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ART. VII.—*The Story of Biela's Comet, a Lecture delivered by* H. A. NEWTON, *March* 9, 1874, *at the Sheffield Scientific School of Yale College.**

LADIES AND GENTLEMEN: I ask you to listen to-night to the story of Biela's comet. I will weave into the story enough of astronomy to justify its place in this course as a lecture.

The story has none of the interest which human passions give to stories of human life, and yet if it shall not be to you as interesting as a novel, it will be because I shall spoil the story in telling it to you. It is a true story. In other words, I mean to separate sharply what we know from what we guess.

One hundred and two years ago last night (March 8, 1772) a Frenchman named Montaigne, in the provincial City of Limoges, found a comet. He did what little he could with his small telescope to mark its place in the heavens, but it was not much that he could do. The comet was a faint one, not to be seen by the naked eye, and had a short tail, only one-eighth as long as across the disk of the moon. He did not dream that that little foggy speck of light was to be one day one of the most interesting comets in the solar system; in fact, that he himself was to be known to history only for having first seen it. This little comet is the hero of my story—a hero from humble life. Montaigne wrote to Paris of his discovery, and they saw it three or four times before it disappeared.

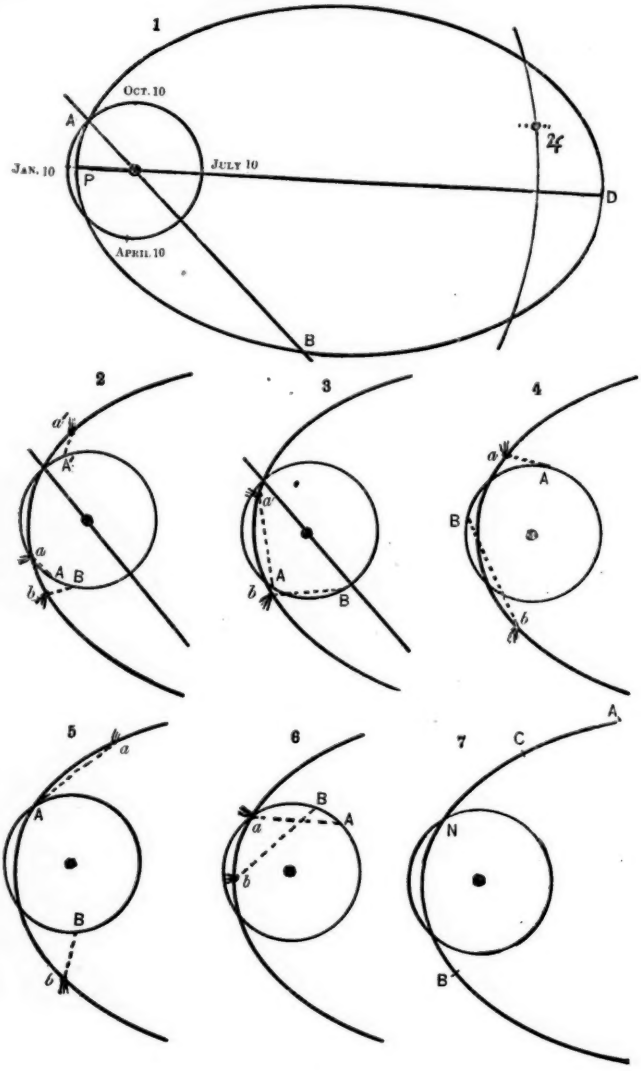
*The renewed interest in Biela's comet created by the great shower of meteors on the 27th of November last, justifies giving space for this lecture.—(EDS. JOUR. SCIENCE.)

Thirty-three years later, November, 1805, another Frenchman named Pons, saw the comet. It passed rapidly from the northern heavens, and in a month went below our horizon. It came this time very close to the earth, and I shall in a moment tell you how it appeared. It was visible to the naked eye, even in strong moonlight. Twenty years later, February 1826, an Austrian officer, Von Biela, again found the comet. So soon as an orbit could be computed, it was seen that the three comets of 1772, 1805 and 1826 were the same body. This has since been known as Biela's comet. Its exact path around the sun could now be told. Let me show it to you.

Let us look down upon the solar system from a point several hundreds of millions of miles north of it. Looking southward we should see the sun in the center. The earth, with its moon, would travel around the sun in a path or orbit denoted by the circle in the figure (fig. 1).

It goes about the sun once a year, being, on the 10th days of January, April, July and October, at the points so marked on the diagram. The motion is opposite to that of the hands of a watch. Outside, five times as far from the sun as is the earth, will be the huge planet Jupiter, a part of whose path you see. It goes about the sun once in twelve years. The paths of the other planets are not in the figure, as I have nothing to say about them to-night. In the figures which I show you the earth's orbit is twenty inches in diameter, or one inch to nine million miles. An express railway train traveling all the time for a fortnight would pass over about the thousandth of an inch in this figure. The comet's path is the ellipse. Around this ellipse it traveled three times in twenty years, or once each $6\frac{2}{3}$ years. When nearest to the sun, or at perihelion, it went within the earth's orbit, and when most distant it passed beyond Jupiter.

The comet's motion is very unequal. At D it moves very slowly. As it falls toward the sun the sun's attraction makes it move faster and faster, so that it whisks rapidly by P. As it then rises from the sun on the other side of the orbit, the sun not only turns it ever out of the straight path it would move in, but it stops its upward momentum, so that when it reaches D again it has only its old velocity with which to repeat its circuit. At P its velocity is twenty-eight miles, at D four miles, a second. In fact, to pass over the part lying apparently outside of Jupiter's orbit, just half of the whole $6\frac{2}{3}$ years is required. I said *apparently* outside, for another fact must be noticed: while Jupiter and the earth may be said to move in the same plane, that of the figure, the comet's orbit, lies at an angle. Suppose the ellipse to be a metal ring, and let it turn about the line AB as a hinge, the part ADB ris-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ing toward you, and the part APD retreating from you. The parts near D must rise about the half-diameter of the earth's orbit to give the true position of the two planes. Notice that the comet's and the earth's orbits cut each other at the node on the line AB. The importance of this fact will by and by appear. The two orbits seem to cut each other at another point (below P), it is true, but because of the angle of the planes the cutting is only apparent.

Like all other comets, this one was visible only when near the earth and near the sun. Through the outer part of its path it was never seen, even with a telescope. The comet was seen in 1826 for the third time.

Positions in 1772 *and* 1805.—In March, 1772, it was first seen from A in the direction A*a* (fig. 2). It was last seen four weeks later from B in the direction B*b*. In November, 1805, Pons found it when the earth was at A′ and the comet at *a*′ (fig. 2). Both the earth and the comet were going to the node, the comet going faster than the earth. The earth passed the node just ahead of the comet. I have told you that the comet was then visible to the naked eye even in moonlight, and well it might be. On the 8th of December, with the scale of the figures before you, it was only $\frac{8}{8}$th of an inch from the earth at the node. On the same scale the moon is $\frac{1}{40}$ of an inch from the earth. The comet passed $\frac{1}{16}$ of an inch outside the earth's orbit, but the earth was already past that point.

Dr. Schröter describes the comet: To the naked eye it was (Dec. 8) a large round cloud of light nearly as large as the moon. In a 13-foot telescope it had the same appearance, though it was much smaller, and it had a bright, star-like nucleus. This nucleus had not sharp edges, not even a definitely round form, but was like a light shining through a fog. Its diameter was about 112 miles, or, if we take only the central light, 70 miles; speaking roughly, as large as the State of Connecticut. The whole cloud, as seen in the telescope, was some 6,000 miles in diameter; to the naked eye perhaps 30,000 miles. How much smaller than 70 miles was the hard part of the nucleus, we cannot say.

Position in 1826.—In 1826 it was first seen from A in the line A*a* (fig. 3). Astronomers followed it with care, as they had come to know that it was a comet of short period, and not many such were then known. Its path then crossed just inside the earth's orbit at the node, but only $\frac{1}{600}$ of an inch in the diagram, or 20,000 miles, in fact, from it.

Position in 1832.—Six and two-thirds years brings us to 1832, and you can readily imagine with what interest this first predicted return was watched for. Some of you also remember the wide-spread, though groundless, fears at that time of a col-

lision of the earth and the comet. The comet was first seen by Sir John Herschel in September. In his 20-foot reflecting telescope he saw it pass centrally over a group of small stars of the 16th or 17th magnitude. The slightest bit of fog would have at once blotted out the stars. Through the comet, however, they looked like a nebula, resolvable, or partly resolvable, into stars. How thick the cometic matter was we do not know. Its extent, laterally, was not less than 50,000 miles. Again M. Struve saw it pass centrally over a star of the ninth magnitude. A like star was seen in the telescope at the same time, so that he was able to say that the comet did not dim in the least the one which it covered. The comet, as the figure (fig. 4) shows, was in 1832 always at a great distance from the earth.

Another six and two-thirds years brings us to 1839. The comet came to perihelion, at P, in July. The earth and comet were on opposite sides of the sun both before and after July, and of course the comet was not seen.

Position in 1845.—Another circuit was finished in 1845–6. The comet was visible then during five months, from *a* to *b* (fig. 5), or as viewed from the sun through nearly half its circuit. At this time it was that the comet became all at once famous.

On the 29th of December Mr. Herrick (then Librarian of Yale College) and Mr. Francis Bradley (then in the City Bank) were watching the comet through the Clark telescope in the Atheneum tower yonder. They saw a small companion comet beside the larger one! What did it mean? Had the comet a satellite like the earth's moon? Or had the comet been split by some convulsion? Two weeks later the companion comet was seen by Lieut. Maury and Professor Hubbard at Washington, and two days after that, it was seen by two or three European astronomers.

Changes were seen in the larger telescopes that increased the mystery. The faint companion grew in size and brilliancy. Each comet threw out a tail. Then the smaller one had two tails. Then the larger one had a pointed, or diamond-shaped, rather than a round head. Two nuclei were seen in the larger one, and it also had two tails. An arch of light was thrown over from one to the other. For some days in February the companion was the brighter of the two. Presently three tails were seen running from the primary, and three cometary fragments (one observer says five) around its nucleus. What could it all mean? Do you wonder that astronomers were excited by these wizard changes?

The companion comet was seen in Washington by Maury and Hubbard two weeks after it was seen here by Herrick and Bradley. Professor Joseph Hubbard was the son of a resident

of New Haven, well-known to many of you from his connection with the New Haven Bank. Professor Hubbard was graduated two years before (in 1843) at this college, and was now Professor in the Naval Observatory at Washington. He took up the study of the motions of the two Biela comets as special work, outside of his hours on duty. How faithfully he worked, four thick manuscript volumes of figures might tell. I cannot show you those books. They form, since Professor Hubbard's death, a cherished memento in the possession of a friend. But I have brought another of Hubbard's volumes from the College Library, one of three upon the comet of 1843, in order to show you by what patient labor some of the results of astronomy must be wrought out. In your school days you called it a wondrously long sum that covered both sides of the slate. On the leaves of this book there are as you see one, two, three, and in some cases, I think, even four thousand figures upon the page. You will, I am sure, excuse me from telling in detail to-night, how we learn about the sizes, distances, and motions of the comets. Eight or ten such volumes of figures, to be increased in time, we hope, by the four Biela volumes, form a monument to a true, devoted, gentle scholar of science. You will not wonder when I tell you that he hated shams.

Positions in 1852.—In 1852 the comet was always at a great distance from the earth (fig. 6), and only to be seen through the largest telescopes. The changes of size and brightness of the two comets were remarkable, and as they could but just be seen, sometimes one and sometimes the other alone was visible; which one it was that a person saw at any time was only told by computation afterward.

The two comets were now eight or ten times as far apart as they had been seven years before. They were at the point P, 1,250,000 miles apart. Professor Hubbard found that he could not tell which comet of 1852 was preceding and which following, in 1845. One supposition agreed as well with the observations as the other.

Perhaps the knowing ones among you have noticed that the arc from the node to the point marked Jan. 10, in the first diagram is too large for one month, for in 1772 the earth passed the node Dec. 9. But you will notice that when the comet is at D, and the large planet Jupiter is near by, he draws the comet toward the plane of the figure. The result is to bring the comet down to meet the earth's orbit farther from P. The node thus went back from Dec. 9 to Nov. 27, a distance of 12 days, or 12 degrees in the circle. The figure represents this last orbit. By the same cause the inclination was reduced one-fourth, or from 17° to 12°.

Since September, 1852 (with one doubted exception to be

spoken of), neither of the two Biela comets has been seen. In 1859 their path was to us behind the sun. In 1866 they should have been at the point P on the 26th of January. A better chance of seeing them could hardly be. They were at all times to be away from the sun's light, and when nearest to the earth not more than one-fifth the sun's distance. The paths were carefully computed, and the action of all the planets, notably that of Jupiter, allowed for. A dozen observers for months swept the heavens with their telescopes, but not the slightest trace of the comets was seen.

Again, they should have come to perihelion a year ago last Autumn (Oct. 6, 1872), but, as I suppose, neither of them was seen. With the loss of its hero, our story would seem to come to an end. I must ask your indulgence, however, for another chapter.

I suppose that each one of you has often seen a shooting star. On a clear night you have seen a bright point of light travel quickly across the sky, as though a star had been shot from its place in the firmament. It may, if it was a large one, have broken into sparks as it disappeared, or have left a cloudy train along part of its path for an instant; or perhaps it was so faint even that you could not be quite sure that you saw anything. Some of you have seen those shooting-stars by hundreds in star showers.

Until near the close of the last century, poets dreamed, and other men guessed, about these objects, but knew nothing. Two German students, Brandes and Benzenberg, found out, and told us, that these bright flights were in the upper parts of the atmosphere. From the two ends of the city a track always appeared to be in the same part of the heavens. But when one went to a village many miles away, a track was seen by the two persons (at A and B, figure 8), in different parts of the sky. Hence they were able to measure the height of the shooting stars from the ground.

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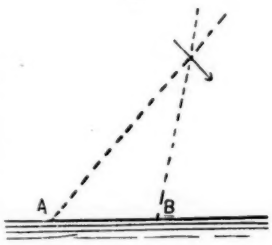

We now know that these luminous paths are rarely less than 40 miles or more than 90 miles from the earth. We also know that any shooting-star was a small body, of unknown size, perhaps not larger than a pebble or a grain of coarse sand even, undoubtedly solid, which has been traveling around the sun in its own independent orbit, like any planet or comet. Its path came within 4,000 miles of the earth's center, and so the small body struck into the earth's atmosphere. Its velocity was so

great—fifty or a hundred times that of a cannon ball—that even in our rare upper atmosphere an intense light and heat was developed by the resistance, and the body was scattered in powder or smoke. These bodies before they come into the air, I call meteoroids. It is only when they have reached our atmosphere and begin to burn that we ever see them. They are then within 90 miles of the ground.

Brandes, one of the two German students spoken of, was riding in an open post-wagon on the night of Dec. 6, 1798, and saw and counted hundreds of these shooting stars or meteors. At times they came as fast as six or seven a minute. These meteors which Brandes saw that night we know now were bits from Biela's comet. In November, 1833, occurred the famous star shower, which some of you saw. The facts of that shower gave to two New Haven men, Professor Twining and Professor Olmsted, the clue to the true theory of the shooting stars. From that date shooting stars have belonged to astronomy. The November meteors were admitted a new constituent of the solar system. Three years later, M. Quetelet, of Brussels, found that shooting stars are to be seen in unusual numbers about the 10th of August of each year. A few months afterwards Mr. Herrick made independently the same discovery; but he also told us of star showers in April and January. What Brandes had seen in December, 1798, led Mr. Herrick, moreover, to expect a like shower in other Decembers, and he asked that shooting stars be looked for on the 6th and 7th of December, 1838. This shrewd guess was justified, for on the evenings of those days hundreds of these meteors were seen in America, in Europe, and in Asia by persons thus induced to look for them. These shooting stars also had once been parts of Biela's comet, though this fact was not dreamed of at that time.

In the course of time we came to know more about the meteoroids; that in general they moved in long orbits like comets, rather than round ones like planets; that some of them were grouped in long, thin streams, many hundreds of millions of miles long, and that it was by the earth's plunging through these that we have star showers; that the space traveled over by the earth has in it everywhere some of these small bodies, probably the outlying members of hundreds of meteoroid streams.

Also the periodic time and the path of the stream of November meteoroids were found out. Then came the interesting discovery that in this stream, and in that of the August meteoroids, lay the paths of two comets. Then Dr. Weiss of Vienna showed that the meteors seen by Brandes in 1798, and by Herrick in 1838, as well as many meteors seen near Decem-

ber 1 of other years, and the Biela comets, all belonged to each other.

It is then properly a part of my story to show you the behavior of one of the streams of meteoroids. Standing several hundreds of miles away, see them enter the upper atmosphere. They are entirely unseen until they strike the air. They then

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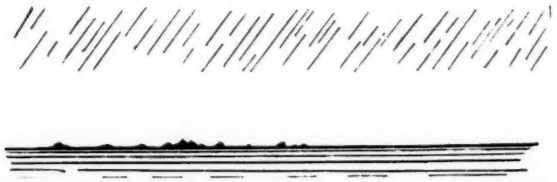

come down like drops of fiery rain a few miles, in parallel lines, burning up long before they reach the ground (see fig. 9). The air is in fact a shield, protecting the men below from a furious bombardment. The region of the luminous tracks is many miles above that of the highest mountains.

Go farther away. Parallel lines may show the paths of the meteoroids, though the bodies themselves are too small to be seen. They strike a little way into the air, to some persons coming from the zenith, to some coming obliquely, to some skimming through the upper air—and unseen by all upon one whole hemisphere. I need hardly remind you that sunlight, and twilight, and clouds often come in to prevent the seeing of the star-flights by persons below.

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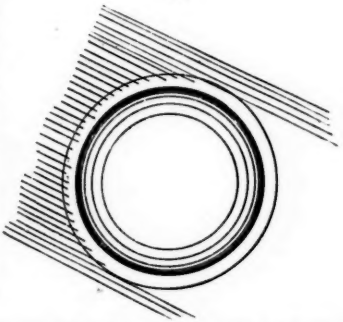

Go still farther away. From outside look in toward the sun upon the earth and meteoroid stream. The meteoroids in fact are not to be seen. The stream is of unknown depth, perhaps millions of miles deep. Its density increases in general toward the center. We cross the densest part of the November stream in two or three hours, and the whole of it in 10 or 15 hours, while the passage of the August stream requires three or four days. The Biela stream is crossed obliquely, the meteoroids overtaking the earth. The August stream is nearly perpendicular, and the November stream meets the earth.

Again go still farther away, out to the point from which we first looked down upon the earth and comet. We then see (by

the mind's eye) the meteoroids strewn along the elliptic orbit of the comet for hundreds of millions of miles, forming a stream of unknown breadth, but in the scale of the first figure shown you, about $\frac{1}{50}$ of an inch in thickness.

Come back now and stand inside the stream, at its densest part. You in fact see nothing; but the meteoroids are all about you scattered quite evenly, and distant each from its nearest neighbors 20 or 30 miles. They all travel the same way and with a common motion.

Once more change your place and look up from the earth's surface. The meteoroids can now be seen, for when they strike the air they burn with intense light, becoming shooting stars. As it is from this position only that we ever see them, note their behavior with more care. A shooting star coming toward you appears only as a bright stationary point in the sky. That point is a marked one in every star shower, and is called the radiant. The meteors to the right and left of the stationary one are, in fact, moving in the common direction, but they seem to move in the sky away from the radiant (fig. 11).

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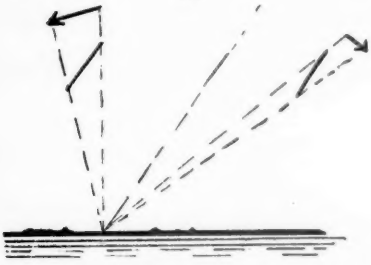

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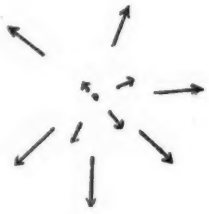


In other words, the tracks produced backward will all meet in one point in the sky (fig. 12). This radiant point may be in the horizon, or in the zenith, or at any place between. It will in general rise in the east and set in the west, like the sun or a star, keeping always its fixed place among the stars.

Need I tell you how much we would like to have some of these bits from the meteoroid streams to handle, to try with the blowpipe and under the microscrope, perhaps thus to learn something of their history? We do have something like this. At times large meteor masses come crashing into the air. They burn with a light bright enough to be seen over several States. Coming down usually a little lower than the shooting stars, most frequently to a height of 25 or 30 miles, they break up with a noise like the firing of heavy artillery, to be heard over several counties. Fragments scattered in every direction fall to the ground over a region ten or twenty miles in extent. I

can show you several such fragments. There are over a hundred of them in our college cabinet, one of which weighs nearly a ton.

Between these stone-producing meteors and the faintest shooting star I cannot find any clear line of division. We have meteors that break with a loud detonation, but no fragments are seen to fall. One such was seen in 1860 from Pittsburgh to New Orleans, and from Charleston to St. Louis. It exploded over the boundary line of Tennessee and Kentucky. We have others which are only seen to break into pieces, no noise being heard. Then we have those which quietly burn out. Like the larger ones, these may leave smoky trains that last for minutes. One such I have seen for 45 minutes as it slowly floated away in the currents of the upper air.

Thus through the whole range, from the meteors that give us these stones and irons for our museums, down to the faintest shooting star hardly seen by a person watching for it, we pass by the smallest differences. They differ in size, in color of flame, in direction, in train, in velocity. But in astronomical character all seem to be alike. They move in long orbits like comets, and like comets at all angles to the earth's orbit. In fact, a meteoroid is a small comet, not having, however, the comet's tail.

Let us turn from this long digression again to the story of Biela and tell you what we saw of it in November, 1872. We of course looked for a few fragments from the comet the last week in November, but not quite as early as the 24th. But on that evening they came, in small numbers it is true. Before midnight we saw in New Haven about 250 shooting stars, three-fourths of them from Biela. Very few of them were to be seen the next morning and evening. Then for a day or two it was cloudy. But in the early part of the evening of the 27th they came upon us in crowds. Over 1,000 were counted in an hour. By 9 o'clock the display was over. But we saw only the last few drops of a heavy shower. Before the sun had set with us the shooting stars were seen throughout all Europe, coming too fast to be counted. At least 50,000, perhaps 100,000, could have been seen then by a single party of observers.

Notice what was really seen. Here is a chart of the paths of the shooting stars as actually seen on that evening, and drawn with care at the time upon maps of the stars. You see a few stray flights cutting wildly across the others. These are strangers to the system.

You see also that the paths do not, as we had reason to expect, all meet in one point. This is not due to errors of observing, for we see it in every star-shower. It is probably

because the small bodies glance as they strike the air, just as a stone skips on the water. In fact, we often see the meteors glance in the air—the paths being crooked.

The meteors came from the northern sky. A German astronomer, Professor Klinkerfues, at once thought that if this

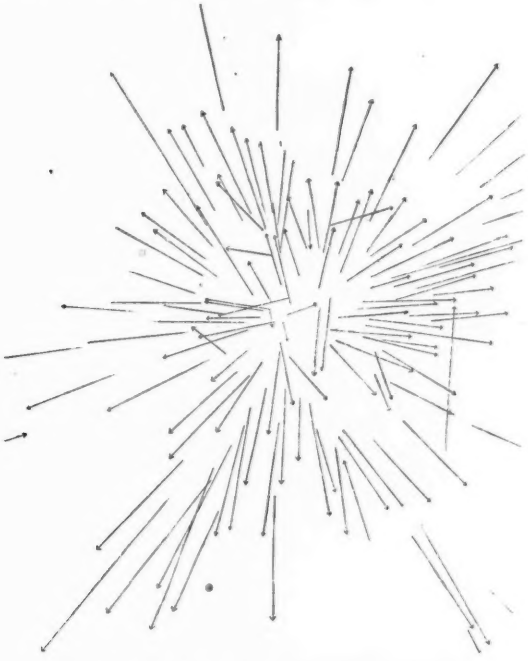


FIG. 13.—METEORS SEEN IN ITALY, NOV. 27, 1872.

was the main body of the comet it ought to be visible as it went off from us. For this, however, we must see the southern sky. He telegraphed to Mr. Pogson at Madras in India: "Biela touched earth Nov. 27. Search near Theta Centauri." Mr. Pogson looked for the comet and found it. On two mornings he saw a round comet with decided nucleus, and having on the second morning a tail eight minutes long. But clouds and rain returned the next day. This is the last that has been seen of Biela's comet.

Was this Pogson comet one of the two parts of Biela seen in 1845 and 1852? This is yet an open question among astronomers. It may have been, but I think it was not. The Biela comets should have been nearly 200,000,000 miles away.

Their orbits had been computed with care. The comets, as single or double, had been observed for 80 years, that is 12 revolutions, and we knew well their orbits. All known disturbing forces had been allowed for. It could hardly be that they should have gone so large a distance out of the way. It is much more probable that this was a third large fragment, thrown off centuries ago. The two observations made by Mr. Pogson were not enough to compute an orbit from, but they do show that his comet was very near us, and were such as one traveling in the Biela stream might give. But they also show that the earth did not pass through the Pogson comet centrally.

Orbit of the Biela Meteors.—In 1798, when the earth was at N, and Brandes saw the fragments from Biela, the comet was at C (fig. 7). In 1838 Mr. Herrick and others saw such fragments of the comet at N, 300,000,000 miles ahead of the main body at A, and in 1872 we met like fragments at N, 200,000,000 miles behind the main body, which should have been at B. Thus the fragments are strewn along the comet's orbit, probably in clusters, for at least 500,000,000 miles.

My story of Biela's comet and of its fragments has covered 100 years. Do we get any glimpses of its earlier life, and can we guess how it grew into its present shape? Yes, we may make our hypothesis. But we must not forget that to tell others how God must have made the world is bewitching to many minds, and that of the thousands of trials at world-building almost all have been grievous failures. With this caution let me give you a plausible form of this early story of Biela.

Once upon a time, hundreds of thousands of years ago, this comet was traveling in outer space, among the fixed stars, too far away to be attracted by the sun. What I mean by this outer starry space may be told by the help of the pictures I have shown you. In them the earth's distance from the sun is 10 inches, and the comet's longest range about five feet. Upon the scale of these figures only a few of the nearest fixed stars, perhaps two or three only, would be in the State of Connecticut. In this starry space the comet was traveling. What had happened before I do not try to guess. How, when, by what changes, its matter came together, and had become solid, I do not know, nor whether, in fact, it had not always been solid.

In the course of time its path and the sun's path through space lay alongside of each other, and the sun drew the comet down toward itself. If the comet had met no resistance as it ran around the sun, whether from the ether that fills space, or from the sun's atmosphere, and if it had not come near any of

the planets, it would have gone off again into outer space whence it came. Some such cause robbed it of a little of its momentum, and it could not quite rise out of the sun's controlling force, but it came around again in an elliptic orbit to remain thenceforth a member of the solar system. It may or it may not then have been a great comet, like Donati's (in 1858). It was probably a small one. It may have made its circuit of the sun in tens of years or in tens of thousands.

At some time, probably in the early historic ages, it came near the huge planet Jupiter. When it had gone out of his reach it had just momentum enough left to go around the sun in its present orbit of $6\frac{2}{3}$ years. It went away from Jupiter an entire and single comet. As it came near the sun, his burning heat acting upon the cold rocky body of the comet cracked off and scattered in every direction small angular bits. At the same time a very thin vapor, shining by its own light, was set free. To this vapor both comet and sun had an unaccountable repulsion. It was driven off first by the comet every way. But soon that which was sent toward the sun was driven back again, and it went streaming off into space to form the comet's tail, a process ably set forth by Professor Norton.

This matter which made the tail of the comet never got back. It had, moreover, nothing whatever to do with the meteoroid stream. The meteoroids are solid fragments. To them the sun, at least, had little repulsion. The comet was so small that perhaps the force with which a boy can throw a stone would have sent the bits of stone entirely off the comet, never to come back. Those which were shot forward from the comet near P (first figure) went up along the orbit with greater velocity and rose higher from the sun than the comet did near D. Having a longer road to travel, they took a longer time to come around to P in each circuit. On the other hand, those bits which were shot backward followed the comet with less velocity and could not quite rise to D, and so having a shorter road to go over came sooner back to P, gaining on the comet at each circuit. Thus the stream grew longer slowly, and new fragments being thrown off at each circuit, the meteoroid stream grew in length to its hundreds of millions of miles. At times, the main comet has broken into two or more parts, giving us the double comets of 1845 and 1852, the Pogson comet of 1872, and the double meteor stream of November, 1872.

ART. VIII.—*Relation between Direct and Counter Electromotive Forces represented by an Hyperbola;* by H. S. CARHART.

IN the usual discussions respecting the relations between the electromotive force (E. M. F.) of the generator, the counter E. M. F. resulting from the electromagnetic reactions taking place in the motor, and the rate at which energy is absorbed by the latter in the electrical transmission of power, it is implicitly assumed that E is constant. Thus the equation, representing the division of the whole electrical energy spent in the circuit in unit time into heat and mechanical work, viz:

$$CE=C^2R+W_{,}$$

is differentiated so as to obtain the first differential coefficient of $W_{,}$ with respect to C, R and E being constants. Hence $\frac{dW_{,}}{dC}=E-2CR=0$ for a maximum, the second differential coefficient being negative. C is therefore equal to $\frac{E}{2R}$, or the current is reduced to half the value it would have with the motor at rest, by the reduction of the effective E. M. F. to one-half.

If, however, we take the equation expressing the electrical energy absorbed by the motor per second as the product of the counter E. M. F. and the current, we have, as is well known,

$$\frac{E_{,}(E-E_{,})}{R}=W_{,} \text{ or } E_{,}(E-E_{,})=RW_{,} \quad . \quad . \quad . \quad (1)$$

From this it appears that if R and $W_{,}$ are constants, $E_{,}(E_{,}-E_{,})$ is also a constant. But when the product of two factors is a constant, their sum is a minimum when they are equal to each other. It follows that the sum of $E_{,}$ and $E-E_{,}$, or E, is a minimum, when $E_{,}=E-E_{,}$, or when $E_{,}=\frac{1}{2}E$. By substitution in equation (1) $E_{,}=\sqrt{RW_{,}}$.

With an assumed amount of work spent upon the motor per second and a given resistance R, E has a minimum value equal to twice $E_{,}$. This corresponds with Jacobi's law of maximum rate of working, or greatest electrical activity and constant E. M. F. Evidently the conditions of greatest activity and constant E. M. F. of the generator are identical with those of constant energy absorbed by the motor and minimum E. M. F. of the generator.

Equation (1) gives

$$E_{,}{}^2-EE_{,}=-RW_{,} \quad . \quad . \quad . \quad . \quad (2)$$

an equation of the second degree and therefore of a conic sec-

tion. On applying the proper criterion it readily appears that the locus of this equation is an hyperbola. For the purpose of a graphical representation of the continuous relation between E and $E_{,}$, let us assume R. $W_{,}$ equal to 225; minimum E will then equal 30 units.

Solving equation (2) for $E_{,}$ and substituting in the result successive different values of E as the independent variable, we obtain corresponding values of $E_{,}$ which satisfy the equation. Each assumed value of E gives two plus values of $E_{,}$. The hyperbola I is thus plotted, making the assumed values of E abscissæ and the corresponding ones of $E_{,}$ ordinates. $E_{,}$ is considered essentially positive.

By a comparison with the most general equation of a conic section, the constants of this particular one may be determined.

Thus independently of the assumed value of $RW_{,}$, $e^2=4\pm\sqrt{8}$ and $e=1{\cdot}0824$, the other value of e making n imaginary. Also $\cos\alpha=\pm\frac{1}{e}$ and $\alpha=22°\ 30'$, the minus value of the cosine not being admissible because then m would become negative. But all values of E are positive, and hence m cannot be negative.

Since the cosine of the angle between the transverse axis of an hyperbola and its asymptotes is the reciprocal of e, it follows that the asymptotes of this curve are the axis of X and the diagonal OG, the angle between them being 45°. The character of the curve is thus entirely determined without knowing the value of $RW_{,}$.

Assuming now $RW_{,}$ equal to 225, the coördinates of the focus are $m = 32{\cdot}96$ and $n = 13{\cdot}65$.

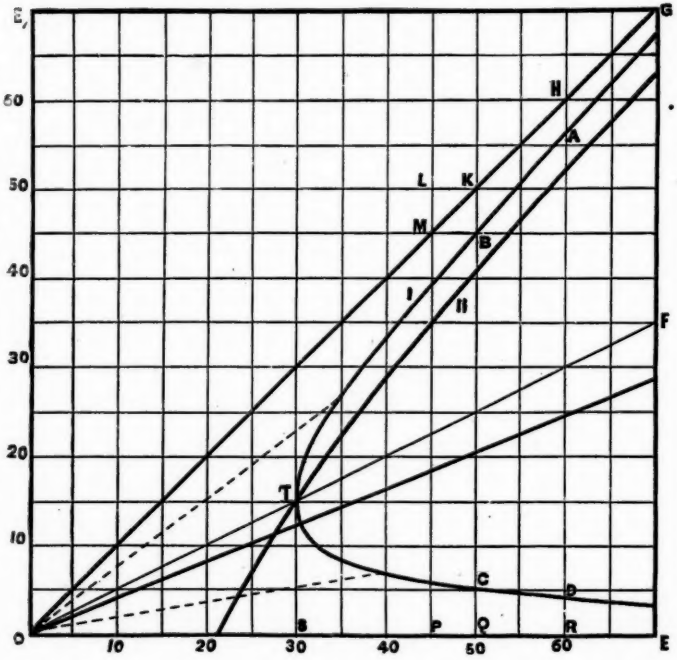
It is evident also from the properties of the hyperbola that m and n in this case equal A and B respectively. The perpendicular distance of the directrix from the origin is 30·45.

A number of inferences can be drawn directly from the curve by inspection. It is seen that E is a minimum when it is double $E_{,}$. At this point the hyperbola is tangent to an ordinate; the point of tangency will travel along the line OF, away from the origin or toward it according as the assumed value of $RW_{,}$ increases or diminishes. OF is therefore the line of minimum E and its equation is $E_{,}=\frac{1}{2}$ E.

The electrical efficiency at any point of the curve, being the quotient of $E_{,}$ by E, is the tangent of the angle which a line drawn from the point to the origin makes with the X-axis. The efficiency at T is the tangent of the angle TOE, or one-half. The electrical efficiency increases from zero, when $E_{,}$ is zero and E is infinite, to unity, when $E_{,}$ equals E and both are infinite; the angle, whose tangent is the measure of the effi-

ciency, is then the angle between the asymptotes, or 45°, and the tangent of 45° is unity. The limits of the efficiency correspond to the points where the curve touches the asymptotes.

It is also evident that near the point where E is a minimum $E_{/}$ increases most rapidly. That is, near the point where the efficiency is one-half it has its greatest increments. Beyond an electrical efficiency of about 75 per cent. the direct and counter electromotive forces increase in nearly the same ratio, and the efficiency therefore increases very slowly.



E and $E_{/}$ denote direct and counter electromotive forces; C current and R resistance in circuit connecting generator and motor; W the total electrical energy contributed by the generator, and $W_{/}$ the electrical energy absorbed by the motor in unit time; e the eccentricity; A and B the semi-axes; m and n the coördinates of the focus of the hyperbola; α the angle between the axis of X and the axis of the conic section.

The diagram shows, further, that $E_{/}$ and C pass through corresponding series of values, but in the inverse order. The current is proportional to $E-E_{/}$, the resistance being constant; and since the intercepts of a secant between an hyperbola and

its asymptotes are equal, that is, AH equals DR for instance, when the counter E. M. F. passes through the series of values represented by the ordinates DR, CQ, TS, BQ, AR in succession, the current will be proportional to AR, BQ, TS, CQ, DR in succession. With the condition that the motor absorbs a constant amount of energy per second, the current is a maximum when the counter E. M. F. and the electrical efficiency are a minimum: and it diminishes continuously as the efficiency increases.

If now the the constant chosen is not the rate at which energy is absorbed by the motor, but the electrical energy contributed by the generator per second, we then have the equation

$$CE=\frac{E(E-E_{,})}{R}=W, \text{ or } E^2-EE_{,}=W \quad . \quad (3)$$

This is again an equation of the second degree and its locus is the hyperbola II. Its axis makes an angle of 157° 30′ with the axis of X and its asymptotes are OG and the axis of Y. Its eccentricity is 2·613, the second value obtained from the equation $e^2=4\pm\sqrt{8}$, the other value being the eccentricity of hyperbola I.

In this case the two machines and the conductor joining them form a system the only condition laid down being the constancy of RW. Hence the relation between E and $E_{,}$ may be found either when the motor is driven by the current and furnishes counter E. M. F., or when it is driven by mechanical means so as to contribute to the direct E. M. F. If the motor is actuated by the current then E has its minimum value when $E_{,}=0$, or at the point where the hyperbola crosses the axis of X; but if the motor dynamo contributes E. M. F. in the same direction as that of the other machine, then E may diminish still further, even to zero in the limit. In this case RW represents still the energy furnished by the generator, but not the total electrical activity per second. The part of the hyperbola lying below the axis of X corresponds to values of E and $E_{,}$ obtained when the motor is driven mechanically so as to furnish direct E. M. F.

In the first curve any assumed value of E greater than the minimum gives rise to two values of $E_{,}$, both positive. In the equation of the second curve the substitution of a positive value of $E_{,}$ gives two values of E, one positive and the other negative, indicating another branch to the curve. This other branch represents the relation between E and $E_{,}$ when the part played by each machine is reversed, the motor becoming the generator, and the generator becoming the motor by being driven electrically.

In curve two the efficiency is measured in the same way as before. Again it is seen to increase as the electromotive forces increase. The current, represented by the intercepts of the ordinates between the hyperbola and its asymptote OG, decreases as the efficiency increases. The same was true in the other case.

It remains only to point out that Jacobi's law of maximum rate of working applies only under the condition of a constant E. M. F. in the electric supply.

This will be evident upon careful inspection of the diagram. The energy spent upon the motor per second is represented by $E_{,}(E-E_{,})$; the electrical energy supplied by the source per second, by $E(E-E_{,})$.

The first expression is the product of the two parts into which the line denoting E is divided at any point by curve I. Since OG bisects the angle between the two rectangular axes, the ordinate of any point of this line equals the abscissa of the points of the hyperbola through which it passes. Thus KQ equals OQ or E, the direct E. M. F. corresponding to the points B and C of the curve. Hence BK equals $E-E_{,}$; and the product of BK and BQ, or the area of the rectangle BMPQ, is the constant RW, of the equation of this hyperbola. The area of all such rectangles is the same for this curve. In a similar way the area of KLPQ is the rate at which electrical energy is supplied to the circuit; and the difference between the two rectangles, or the square KLMB, is the heat waste per second at this point of the curve.

Now while the area of the first class of rectangles is the same for all points of the curve, that of the second and of the squares diminishes as $E_{,}$ and the efficiency increase from point to point along the curve in the direction D, C, T, B, A.

If the same analysis is applied to curve II it will be found that the area of the rectangle expressing the electrical work spent upon the motor per second increases, the rectangles denoting the rate at which energy is supplied by the generator all equal RW, and the area of the square representing the waste in heat diminishes from point to point, as E, E, and the efficiency increase.

We may therefore distinguish three cases, R being constant in each case:

First, When E is constant.

Then $W_{,}$ is a maximum when $E_{,}$ is half E by Jacobi's law.

The electrical efficiency increases with $E_{,}$.

The current diminishes as $E_{,}$ increases.

W diminishes from a maximum to zero when the efficiency is unity.

Second, When $W_{,}$ is a constant.
Then E is a minimum when $E_{,}$ is half E.
The electrical efficiency increases with $E_{,}$.
The current diminishes as $E_{,}$ increases.
W diminishes from infinity to $W_{,}$ when the efficiency is unity.
These are the limits.

Third, When W is a constant.
Then $W_{,}$ is a maximum only when the efficiency is unity, in which case E and $E_{,}$ are infinite.
E has a minimum value of $\sqrt{RW}$ when $E_{,}$ is zero.
(The case of the motor driven mechanically is not included.)
The electrical efficiency increases with $E_{,}$.
The current decreases as $E_{,}$ increases.

Jacobi's law applies only to the first case. When a battery is to be employed to run an electric motor, then E is the proper term to consider constant; but if it is required that the motor furnish a definite amount of power, then the graphical illustration of hyperbola I shows that E has a minimum value and points out some of the conditions of high efficiency.

Art. IX.—*Tendril Movements in Cucurbita maxima and C. Pepo;* by D. P. Penhallow.

(Continued from page 57.)

Observations upon the movement of both tendril and terminal bud were made both day and night for an entire week, and thus the motion of each arm, for almost its entire period of activity, was secured. Temperature and other meteorological conditions were noted at each observation, taken during the night at intervals of an hour—sometimes less—and during the day as often as seemed necessary from the activity displayed, thus frequently at intervals of two minutes.

Tendril No. 1.

At 9.30 in the morning of August 12th, one of the longest arms was selected after it had been sometime uncoiled, and its movements were noted until there was no further motion. The entire time over which the observations extended was ten hours and thirty minutes. During this time, the tendril tip traversed a distance of $343{\cdot}15^{cm}$, giving an average movement of $0{\cdot}54^{cm}$ per minute.

The greatest rate of movement at any one time was $2{\cdot}06^{cm}$ per minute, and occurred two and one-half hours after the wave of maximum temperature had passed. The waves of most rapid motion extended from 2.30 to 4.30 P. M., closely

following the greatest heat wave. The waves of slowest motion covered the time from 10 A. M. to 2.30 P. M., coincident with a rising temperature. The absolute minimum of motion occurred just before the maximum of temperature and was at the rate of 0·21^{cm} per minute. At 4 o'clock in the morning, a heavy rain ceased. The air was still surcharged with moisture, and the sky was entirely overcast with heavy clouds. It was while this condition lasted that the waves of slowest motion occurred, the minimum being found during the interval from 12.15 to 1 P. M. At the latter hour the clouds broke and the sun came out brightly and so continued until 6 P. M., when the sky again became overcast and rain set in at 7 o'clock. While the sun was out, the tendril was most active, absolute maximum of movement taking place in the five minutes from 3.25 to 3.30 P. M., the whole distance traveled in that time being 16·30^{cm}.

The first direction of movement was to the right. This, however, was obviously purely accidental, since the direction first recorded must depend upon the time of first observation, dextrorse alternating with sinistrorse action during the whole movement of the tendril. The entire motion to the right amounted to 190·8^{cm}; that to the left reached a total of 152·35^{cm}; the ratio of the one to the other thus being as 1 : 0·79.

Tendril No. 2.

The second tendril was selected on the 13th of August, at 8 o'clock A. M. It was a shorter arm than No. 1, and rather nearer the end of its activity. The time of movement was six hours and fifteen minutes, and the entire distance traveled was 136·00^{cm}, thus giving an average rate per minute of 0·36^{cm}.

The absolute maximum of movement was 1·76^{cm} per minute and occurred from 10.15 to 10.20 A. M., forty-five minutes before the maximum temperature for the day was reached. The waves of most rapid movement covered the time between 8 and 10.50 A. M., coincident with increasing temperature. The waves of least motion occurred between 10.50 A. M. and 2 P. M., during a slight depression of temperature. The absolute minimum was reached between 10.50 and 12.15 M., and amounted to 0·179^{cm}. It directly succeeded the maximum of temperature. During the entire time of observation, the weather was very pleasant, though somewhat cloudy. At twelve o'clock, the leaves began to droop from the effects of excessive transpiration and heat. This continued until after the close of observation. It was during this time of depressed activity and reduced tension, that the minimum of motion occurred. During the entire morning, all the leaves and flowers showed great vigor, and it was while in this condition that most active move-

ment took place. The first motion observed was to the left, and was not replaced by dextrorse movement for some time. The entire sinistrorse action was 94·20^{cm}. The dextrorse was 41·80^{cm}, a ratio of the latter to the former of 1 : 2·25.

Tendril No. 3.

The time of observation was ten hours and thirty minutes, commencing at ten o'clock A. M., on August 13th. The total length of movement was 329·30^{cm}, and the average rate per minute was 0·52^{cm}. The times of greatest movement were from 1 to 3.15 P. M., and from 5.15 to 8 P. M.; the former occurring at the time of the wave of maximum temperature, the latter during a diminishing temperature. The absolute maximum of motion was 3·55^{cm} per minute, and occurred during the two minutes from 1.50 to 1.52 P. M., succeeding the maximum temperature by two hours and fifty minutes, at a time when there was a slight temporary depression of temperature. The distance traveled in this short interval was 7·10^{cm}.

The time of least motion was from 12.15 to 1 P. M., during the time of greatest heat, and again from 3.15 to 5.15 P. M., following a diminution of temperature. The absolute minimum of motion was 0·013^{cm} per minute, and occurred from 12.15 to 1 P. M. on a decreasing temperature, and following the maximum temperature by one hour and fifteen minutes. During this time, the weather was pleasant but somewhat cloudy. From 11 A. M. until 5 P. M. all the leaves and flowers were drooping, indicating a weak vital action through excessive transpiration.

The first movement recorded was to the right, soon succeeded by a reverse to the left. The entire amount of the former was 261·50^{cm}; of the latter, 67·80^{cm}; the ratio of dextrorse* to sinistrorse being as 1 : 0·25.

Tendril No. 4.

This tendril was taken August 14th at 8 o'clock A. M., but so late in its growth that only twelve movements were obtained. These covered seven hours and fifty minutes in all. The whole length of movement was 66·20^{cm}, and the average rate per minute was 0·14^{cm}. At no time was there any exhibition of very great activity, the tendril appearing to move as if in the last stages of growth, which it really was. The most rapid movement appeared at 9.41 to 9.50 A. M., the extremity passing through 7.70^{cm} in nine minutes, an average rate of 0·85^{cm} per minute. This coincided with the highest temperature and was just prior to a fall of two degrees. The time of

* Dextrorse and sinistrorse are applied upon the supposition that we stand at the base and look to the tip of the tendril.

least activity was from 9.50 A. M. to 3.50 P. M. The absolute minimum of motion was from 2.10 to 3.50 P. M., amounting to 0·031^{cm} per minute. It occurred on a decreasing temperature, five hours and fifty minutes after the maximum temperature had passed. During this time the sun was shining brightly, though its effect was somewhat modified by numerous clouds. From twelve o'clock to the close of observations, during the time of least activity, the leaves and flowers were all depressed from the effects of the heat. The movements as first recorded were to the left, but after two courses changed to the right. The total dextrorse movement was 18·4^{cm}; the sinistrorse 47·80^{cm}; thus giving a ratio of 1 : 2·6.

Tendril No. 5.

No. 5a.—This tendril was selected August 13th at 4 P. M., as soon as it had straightened out from the bud, and very nearly the first nutations were obtained. Observations were interrupted after a few hours and not resumed until the next morning. The entire length of movement was 107·60^{cm}, occupying four hours and thirty minutes, thus giving 0·39^{cm} as the average rate per minute. The greatest movement was at the rate of 1·44^{cm} per minute and occurred from 4 to 4.05 P. M., at the very commencement of action and observation. The time of greatest movements occurred from 4 to 4.35 P. M., and again from 5.30 to 7 P. M., coincident with decreasing temperature.

Least activity was noticed at 7.55 to 8.10, when the tip moved at the rate of 0·13^{cm} per minute. This occurred at the time of lowest observed temperature, the thermometer standing a 21° C. The time of best movements was found to extend from 4.35 to 5.30, and again from 7 to 8.50 P. M., when the observations ceased.

At the commencement of observations, the sun was shining brightly and its effect was sufficiently strong to cause a depression of all the leaves and flowers. Shortly after observations ceased, the sky became cloudy, and at nine o'clock there was a heavy shower, which revived the plant and brought all the parts once more into active condition. The first recorded movement was to the left, action in this direction predominating during the time of observation. The entire movement to the right was 18·80^{cm}; that to the left was 88·80^{cm}, giving a ratio of 1 : 4·72.

No. 5b–c.—This tendril was the same as 5*a*, observations upon which were interrupted at 8.30 P. M., August 13th, and resumed the next morning at 8 o'clock, continuing through the 14th and 15th. During the night the arm was quite active, and in the morning showed no tendency whatever to discon-

tinue its nutations. From the time indicated, observations were continued for twenty-three consecutive hours. The entire distance traveled during that time was 511·70^{cm}, thus giving an average rate of 0·37^{cm} each minute. The number *5b–c* was given to indicate a change of recording papers. This occurred at 6.20 P. M., at a time when the tendril tip had drooped to the ground and did not resume its movement until 8.35 P. M., when the nutations continued as before.

The time of most rapid movement was during the two minutes from 4.55 to 4.57 P. M., on a descending temperature, and five hours after the maximum wave had passed. The total rate of movement was 4·55^{cm} per minute. The times of most rapid movements occurred from 8 to 10.20 A. M.; 1.30 to 2 P. M.; 4 to 5 P. M., and 10.53 to 11.05 P. M.; the maximum of these being from 4 to 5 P. M. The absolute minimum of motion occurred from 4 to 5.04 A. M., when the tip traveled at the rate of 0·043^{cm} per minute, this being at a time of low temperature. The times of least movement were from 10.20 A. M. to 1.30 P. M.; 2 to 4 P. M; 5.30 to 10 P. M. and from 11.05 during the remainder of the night and until the end of the experiment at seven o'clock in the morning. There appears in these observations a very sharp division at 5.30 P. M., between the waves of more rapid daily movement and the waves of slower motion during the night.

The experiment commenced with very pleasant weather and all parts of the plant in vigorous condition, the leaves being erect and the flowers open. From 12 M. to 4 P. M. the leaves were drooping and the activity of the plant small. This, with the exception of one-half hour from 1.30 to 2 P. M., was a time of slow movement. At 4 o'clock P. M., the leaves began to resume their normal, fresh appearance, and so continued until the close of observations. Towards morning a very heavy fog gathered and reached its maximum at four o'clock, the time when the absolute minimum of motion occurred.

Sinistrorse movement was first noticed. In the movements of this tendril, there appeared a greater equality between right and left motion than was noticed in any of those previously experimented upon. The entire dextrorse movement was 282·10^{cm}; the sinistrorse 229·60^{cm}, a ratio of 1 : 0·81.

Tendril No. 6a–b.

As in the preceding case, the letters *a–b* designate a change of paper. This occurred at 7 o'clock P. M., while the tendril was quite active, but it in no way disturbed the movement. The filament was selected August 14th at 1.15 P. M., when a short time from the bud, and observations were continued consecutively for eighteen hours and fifteen minutes. The dis-

tance traveled by the tip during this time was 327·80^{cm}, an average of 0·29^{cm} per minute.

Most rapid movement occurred from 6.50 to 6.52 P. M., at the rate of 6·50^{cm} per minute. This was on a decreasing temperature, and six hours and fifty minutes after the wave of maximum temperature had passed. The time of greatest movement was from 3.50 to 7.10 P. M., on a decreasing temperature. The least motion was 0 047^{cm} per minute, and occurred at 11.25 A. M. to 12.35 P. M., on a decreasing temperature, and within three degrees of the lowest phase of the thermal wave. The times of least movements were from 1.15 to 3.00 P. M., and from 7 P. M. to the close of observations. As in tendril 5 *b c*, there was in this a noticeable distinction between the waves of more rapid diurnal motion, and those of slower nocturnal movement. The time of division was 7 P. M.

The tendril commenced action with a dextrorse movement, and here was noticed a greater equality between right and left than in even the previous case. The whole movement to the right was 166·10^{cm}; that to the left 161·70^{cm}, the ratio, therefore, being as 1 : 0·97.

At the commencement of observations, the sun was bright and the temperature high. The vitality of the plant was much depressed and the action slow, all the leaves drooping from excessive transpiration. This continued until 4 P. M., during which time there were slow waves. At 4 o'clock the plant revived, the leaves became erect and the normal condition and activity were once more restored. From that time until sunset, the waves of greatest movement occurred. The sky was clear until after midnight, but slow waves continued throughout the remainder of the night, with a slight acceleration just after sunrise.

Tendril No. 7.

No. 7a.—Observations commenced August 16th, at 9 o'clock A. M., and were continued for ten consecutive hours. The total distance over which the tip moved during this time was 227·10^{cm}, or at the rate of 0·38^{cm} per minute.

The time of most rapid movement was from 5 to 5.20 P. M., when the tip moved 0·92^{cm} per minute. This occurred just at the outset of a rapid decline in temperature, and six hours after the maximum of temperature had passed. The time of greatest movements was from 3.15 P. M. to the close of observation at 7 o'clock, and was coincident with a rapid decline in temperature. The time of least movement was from 1.42 to 2.25 P. M., the tip moving at the rate of 0·053^{cm} per minute. This was during high temperature, but one hour and forty-two minutes after the maximum had passed. The waves of least motion were found from 9 A. M. until 3.15 P. M., with a marked

retardation toward the latter hour. These waves were coincident with the greatest heat wave, the greatest retardation of motion occurring after the maximum of heat had passed.

The experiment commenced with the sky clear and the plant in an active condition. As the heat increased, however, its effects upon the plant were noticed, and at 12 o'clock, with the thermometer at 34·4° C., the leaves drooped and the whole plant was in a very flaccid condition. During this time the waves of slowest motion occurred. This condition continued until, with considerable fall in temperature during the afternoon, the normal tension and activity of the plant were restored, when the waves of greatest movement were noticed. The entire dextrorse movement of the tendril was 92·90^{cm}, the sinistrorse 134·20^{cm}, and the ratio was, therefore, as 1 : 1.44.

No. 7b.—This was the same as the preceding, observations upon which were discontinued during the night, but resumed on the morning of the 17th at 8 A. M., and carried over a period of seven hours and fifty minutes. The entire movement during this time was 94·40^{cm}, giving an average rate per minute of 0·205^{cm}. Most rapid movement was at the rate of 0·555^{cm} per minute, and occurred from 8 to 8.15 A. M., at the very commencement of observations and on a rising temperature, six hours before the maximum was reached. The waves of most rapid motion were found from 8 to 11.30 A. M. Least movement took place at 1.30 to 2 P. M., at the rate of 0·08^{cm} per minute. This was just at the time of maximum temperature. The waves of least motion were found from 11.30 A. M. to the close of observations at 3.40 P. M., coincident with a rising and maximum temperature.

Observations commenced with moderate temperature, clear sky and an active condition of the plant, continuing thus during the time of greatest movement until, at 11 o'clock, the leaves became depressed from the effects of heat, and from 11.30 on, the waves of slow motion were found. At 12 M. the sky was overcast and the air loaded with moisture. At 1 P. M. the leaves were restored to their normal condition and erect position. At the same hour rain commenced and continued during the remainder of the experiment.

The total movement to the right was 25·10^{cm}; to the left 69·30^{cm}, and the ratio was, therefore, as 1 to 2·76.

Tendril No. 8.

No. 8a.—This filament was selected August 16th at 9 A. M. The time of observation covered a period of nine hours and fifty minutes, or until 6.50 P. M. The entire movement during this time was 314·50^{cm}, giving an average rate per minute of 0·516^{cm}. The time of greatest movement was from 3 to 3.15

P. M., and the rate per minute 1·20^{cm}. This was on a decreasing temperature, four hours and fifteen minutes after the maximum. The waves of greatest movement were found from 2 P. M. until the end of observations, and during a diminishing temperature. The time of least movement was from 11.25 to 11.40 A. M., and the rate per minute 0·166^{cm}. This was at the time of maximum temperature. The waves of slowest movement extended from 9 A. M. until 2 P. M., with slight acceleration of movement toward the latter hour.

Observations commenced with a bright sun and the plant in active condition. At 12 o'clock the leaves drooped, with the thermometer at 34·4° C., and this condition continued until early in the afternoon, when they revived, with decrease of heat. It was during the passive condition of the plant that the slowest movements were observed, the more rapid waves occurring with renewed vigor and active condition. The entire dextrorse movement was 143·10^{cm}; the sinistrorse 161·40^{cm}, and the ratio was, therefore, as 1 : 1·12.

No. 8b.—Observations were resumed at 8 o'clock A. M. of August 17th, and were extended over seven hours and forty-nine minutes. The distance which the tip traveled during this time was 225·00^{cm}, or at the rate of 0·483^{cm} per minute. The greatest movement was at the rate of 2·60^{cm} per minute, occurring from 3.40 to 3.45 P. M., at the very close of observations, and one hour and forty-five minutes after the maximum of temperature. The waves of most rapid movement were from 3.15 to 3.45 P. M.

Least movement occurred at 10.15 to 10.30 A. M., at the rate of 0·10^{cm} per minute. The waves of least motion extended from 8 A. M. until 3.15 P. M., coincident with a rising and maximum temperature. Observations commenced with a bright sun and the plant active. At 11 o'clock A. M., just thirty minutes after the minimum of motion occurred, the leaves were all drooping as a result of excessive transpiration. At 1 o'clock P. M., it was raining, and the normal activity of the plant was restored. This continued until the close of observations. The entire dextrorse action was 103·50^{cm}; the sinistrorse 121·50^{cm}, and the ratio therefore as 1 : 1·17.

No. 8c.—Observations upon No. 8*ab* were resumed on the 17th of August at 5 o'clock P. M. and extended over fifteen hours. Apparently on account of its age, and the time of observation, the entire movements were slow, amounting in the fifteen hours to only 159·00^{cm}, giving an average rate per minute of 0·176^{cm}. The greatest movement was at 7.12 to 7.28 P. M., at the rate of 0·65^{cm} per minute. The waves of most rapid movement were from 5 to 7.30 P. M., with a slight acceleration in the morning. Least movement was found at 2.30 to

3 P. M., at the rate per minute of 0·023^{cm}, occurring at the time of minimum temperature. The extreme variation of temperature during the hours of observation, was only 2° C. A light rain fell during the greater part of the time, and heavy clouds obscured the sky the remainder. The movement to the right was 117.60^{cm}; to the left 41·40^{cm}, and the ratio therefore, as 1 : 0·35.

Tendril No. 9.

The last tendril experimented with was selected August 17th at 6 o'clock P. M. It was in the last stages of movement, and exhibited the least horizontal movements of any upon which observations were taken. The whole length of movement was 191·30^{cm}; the time sixteen hours and forty minutes, and the consequent average rate per minute was 0·191^{cm}.

The greatest movement was from 7 to 7.06 A. M., at the rate of 2·17^{cm} per minute. This occurred in a slightly increasing temperature. The waves of most rapid movement were from 5 to 9 A. M. The least movement occurred from 9.30 to 10.00 P. M., at the average rate of 0·02^{cm} per minute. The waves of slowest movement were found from 6 P. M. until 5 A. M.

The temperature varied only three degrees during the entire time of observation. From the commencement until 10 o'clock P. M., light rain fell and the sky was entirely overcast until the close of observations. At 5 A. M., there was a cool east wind with a very large amount of moisture in the air, and the plant was apparently in a very active condition. At the close of observation, heavy rain commenced to fall. The total dextrorse movement was 160·40^{cm}; the sinistrorse 30·9^{cm}; and the ratio as 1 : 0·181.

Terminal Bud.

For experiment, there was selected a good terminal bud upon the extremity of a vigorous vine growing directly from west to east. The observed movements were chiefly in vertical direction, those in a horizontal plane being, apparently, not so conspicuous. The total movement was 96·90^{cm} at the average rate of 0·065^{cm} per minute, the observations extending over fifteen hours and twenty-eight minutes. As might be expected, this movement was much slower than that of the tendrils, but at the same time, sufficiently rapid and continuous in a given direction, to make the observations very easy. In this circumnutation, geotropism and heliotropism exert an important influence upon the figure described by the tip as the result of growth. The end of the vine is constantly turned upward, and during a certain time becomes more and more elevated, finally falling back towards the ground. This is repeated continually during the entire growth of the vine, the change usually taking place once each day.

The greatest rate of movement was found to be 0·42^{cm} per minute and occurred from 10.10 to 10.40 A. M. on a rising temperature. The least movement was from 11.30 to 12 M., at the rate of 0·013^{cm} per minute.

During the time of observation, the temperature was quite uniform, varying only three degrees. The sky was overcast during the night and the air was loaded with moisture. At 5 A. M. there was a cold east wind, but this did not seem to interfere with the activity of the plant. The closing observations were taken in a hard rain, which commenced at ten o'clock. The entire dextrorse movement was 60·10^{cm}; the sinistrorse 36·80, and the ratio as 1 : 0·61. The whole range of vertical movement in which the effect of geotropism was very evident, was 17·60^{cm}; negative heliotropism (?) 16·90^{cm}; positive heliotropism (?) 10·30^{cm}.

Collateral to the observations concerning movements, it was deemed wise to collect all other facts which, through any explanation of the general phenomenon of growth they might afford, would throw light upon the special question under consideration. It was with this view that the following facts concerning growth in both vine and fruit were collected.

Growth of the vine.

To determine the hourly growth of the vine, a board, suitably marked off into a scale of inches and tenths, was placed in a vertical position at one side of the growing extremity and parallel with it. The scale was placed at one side rather than beneath in order to avoid inaccuracy which might arise through the vertical movement of the terminal bud, which would of course, at times, bring it some distance from the scale. Readings were taken every hour. Observations were continued for 158 hours, almost consecutively. The entire growth of the vine during that time was 89·40^{cm}, giving an average hourly growth of 0·566^{cm}. The most rapid rate of growth was 1·015^{cm} per hour. This rate was reached eight times out of the 158 and, with one exception, occurred at noon, between the hours of 12 M. and 2 P. M. This rate was also obtained under the influence of high temperature.

The slowest rate of hourly growth was 00·00^{cm}. This occurred only once, at 8 o'clock P. M., and was due to no apparent cause. Minimum movements of 0·253^{cm} frequently occurred The waves of least movement were obtained at or soon after midnight, consequently at a time of low temperature.

The entire growth of the vine during the night was 34·287^{cm}.* The entire growth during the day was 44·447^{cm}, and the ratio

* All the observations are not included here, as some must of necessity be left out to equalize hours of day and night.

was thus as 1 : 1·29. The hours of night were reckoned from 7 P. M. to 7 A. M., consequently those of day from 7 A. M. to 7 P. M. The average rate of growth for the night was found to be 0·49^{cm} per hour, that for the day 0·633^{cm}, or as 1 : 1·29.

The hourly variations were much more regular when the temperature was low, or, under a high temperature when, owing to the moisture in the air, transpiration was not excessive and the normal tension of the tissues was maintained. When, however, under conditions of high temperature and dry atmosphere, transpiration was great and all the leaves, flowers and terminal bud drooped in consequence of the resulting release of tension, then the variations became more irregular. We find then, so far as this goes, that while growth is continued through the night, it is much greater during the day; that the higher the temperature the more rapid the growth; that excessive transpiration interferes with regularity in growth and even retards it.

Growth of the Squash.

To determine the rate of growth in the squash, and the modifying conditions, care was taken to select a young fruit without blemish, and to preserve the vine upon which it grew from injury. One of Fairbanks' platform scales was drawn close to the vine and securely fixed in position. Upon it was then placed a wooden cradle adapted to the form of the squash. The latter was allowed to lie upon a layer of hay to preserve it from injury. The vine was carefully drawn up and allowed to pass by one end of the cradle. The whole arrangement was carefully balanced before and after placing the squash, and the latter was found to weigh just 61 pounds, at the beginning of the experiment. The weight was taken every day at one o'clock P. M. The following table will show the results.

Growth of the Squash.

Date.	Mean temp.	Total weight.	Daily increase.
Aug. 9,	24·0° C.	61	0·0
10,	25·1	64	3·0
11,	23·1	67	3·0
12,	23·9	72·5	5·5
13,	23·9	75·5	3·0
14,	24·9	77·5	2·0
15,	25·9	80·0	2·5
16,	24·2	83·0	3·0
17,	21·7	86·0	3·0
18,	19·3	88·5	2·5
Totals,	235·9	755·0	27·5
Means,	23·59° C.	75·5	3·05

From this it will be seen that the entire gain in weight, during the nine days of experiment, was 27·5 pounds, or a daily average of 3·05 pounds, the greatest gain for any day, occurring August 11th and 12th, and amounting to 5·5 pounds for the twenty-four hours. During this time the sky was obscured by rather heavy clouds, and showers were of frequent occurrence. The temperature was moderately high, the average for the twenty-four hours being 22·6° C.

The least gain was noticed August 13th and 14th, and amounted to 2·0 pounds. During the hours of day, the transpiration from the plant was excessive, and all the leaves, buds and flowers were drooping. During the night, there was a light shower. The temperature was quite high, averaging 25° C. for the twenty-four hours. About the first of September, when the squash was taken from the scales, it weighed 96 pounds.

General Summary.

Average rate of movement. It is tolerably safe to assume that, from an aggregate of 436 distinct and complete observations upon the motion of the tendrils under all conditions of temperature, sun and humidity, some figures can be obtained which will represent pretty nearly, the true normal rate of movement, under all the conditions to which the plant is ordinarily subjected. This we find to be 0·351^{cm} per minute.

Maximum rate of movement. By reference to the following table, it will be possible to trace the relation which movements of greater and less rapidity bear to the temperatures for corresponding periods, and thus determine the specific influence of higher or lower temperature in promoting activity.

Relation of Rate of Movement to Temperature. Degrees C. Distances in centimeters.

	1	2	3	4	5*a*	5*bc*	6*a-b*	7*a*	7*b*	8*a*	8*b*	8*c*	9	Means.
Average rate per minute.	0·54	0·36	0·52	0·14	0·39	0·37	0·29	0·38	0·205	0·516	0·483	0·176	0·191	0·351
Max. rate of movement..	2·06	1·76	3·55	0·85	1·44	4·55	6·50	0·92	0·555	1·20	2·60	0·65	2·17	2·216
Tem. for max. rate move...	28·3	26·1	27·8	35·5	27·2	30·9	24·4	29·0	20·0	31·7	22·2	20·5	21·1	26·5
Minimum rate of movem'nt	0·21	0·18	·013	·031	0·13	·043	·047	·053	0·08	0·166	0·10	0·023	0·02	0·84
Tem. for min. rate move...	31·1	31·7	29·5	32·2	21·7	16·7	21·1	31·1	22·8	34·0	24·0	19·5	20·0	25·8

We find that of the thirteen sets of observations here given, only four show waves of rapid movement during the morning, these occurring between the hours of 7.00 and 10.20, and in no case,—unless we make exceptions in favor of No. 9—representing the absolute maximum of movement for the entire life of the tendril. The remaining nine show the waves to occur in

the afternoon from 1.50 to 7.12 o'clock. If we now select those figures under 1, 3, 5 *b–c*, 6 *a–b*, 8 *b*, and 9,* representing the true maximum rate of motion in those tendrils for the entire period of their activity, we will find that only one occurred in the morning, all the others taking place in the afternoon between the hours of 1.50 and 6.50.

Selecting an equal number of hours of day and night, making the hours of division 7 A. M. and 7 P. M., we find that we obtain a total length of diurnal movement of 1359·90^{cm}; and of nocturnal movement of 536·90^{cm}, thus making the latter in the ratio of 1 : 2·53 to the former, a difference which clearly indicates that temperature exerts an influence far outweighing any retarding effect upon growth which direct and bright sunlight may have.

This naturally brings up a question relative to the temperature at the time these figures were taken. The six figures already selected as representing the maximum movements, were found while the temperature ranged from 21·1° to 30·9° C. Of these, the highest, viz: 6·5, 4·55 and 3·55^{cm} were found when the temperature ranged from 24·4° C. to 30·9° C.; the other three giving us 2·17, 2·6 and 2·06^{cm}, were obtained between 21·1° and 28·3° C. We thus find that the more active of these waves were formed under the influence of a temperature 3·8° C. higher than that under which the less active were produced. We also observe that while the more rapid movements are propagated under medium temperature, the slower movements are developed under the *extremes* of temperature, some higher, some lower. And yet again, that in the *means* of all the values of each kind, the more rapid movements are developed under a somewhat higher temperature than the slow movements, thus indicating that while excess in either direction is detrimental, higher temperatures are best adapted to the most rapid growth so long as they fall within certain limits.

Pursuing this line of thought yet a little further, and taking the highest rate of each tendril movement—including, therefore, the six first considered—we find them obtained under an average temperature of 27·2° C.; while those waves of rapid movement belonging to the same tendril, but of less amplitude, were propagated under an average temperature of 24·8° C. Of the thirteen maxima of movement obtained, one was found to be coincident with the absolute maximum of temperature. This, however, was a movement at the low rate of 0·85^{cm} per minute. Three were found to occur on an increasing temperature, usually several hours before the maximum was reached;

* The remaining are not taken for the obvious reason that, as the tendrils to which they belong were in the last stage of movement, they do not represent the point now under consideration.

and nine were found to occur on a descending temperature, from two to six hours after the maximum for the day had passed.

Passing to the conditions of humidity, we find that the maximum movement of tendrils 1, 8*b*, 8*c*, and 9, were reached under conditions of great humidity, of all the remainder, when the sky was clear and the sun bright. The rates of movement, in the four tendrils first mentioned, were respectively 2·06, 0·65, 2·6 and 2·17^{cm}, and were obtained when, owing to the humidity of the air, transpiration was not very active. Tendrils 2, 3, 4, 5*a*, 7*ab*, and 8*a*, gave respectively 1·76, 3·55, 0·85, 1·44, 0·92, 0·555, and 1·2^{cm}, as their maxima of motion. These values were obtained while transpiration was excessive, its effect upon the plant being so great, that all the leaves and terminal buds were drooping. Tendrils 5*bc*, and 6*ab*, in which the highest maxima were reached, gave respectively 4·55 and 6·50^{cm}, but these values were reached under conditions of active, though not excessive transpiration, clear sky and bright sun, while the whole plant was in a normally active condition, as shown by the erect leaves and fine healthy color of all parts. The mean rates of movement under the conditions first discussed, show an average of 1·43^{cm}, under conditions of favorable humidity, and 0·707^{cm}, when the air was unfavorably dry, showing that a due amount of moisture in the air is more favorable to growth than its absence, in the ratio of 1 : 0·494.

Minimum rate of movement.—Of the thirteen minimum movements recorded, we find that five occurred between sunset and midnight, two between midnight and sunrise, three between 10 A. M. and 1 P. M., and three between 1 P. M. and 4 P. M. We further find that four occurred during a minimum temperature; four just before the maximum; two just after and three at the very time of maximum temperature. As in our previous division, taking the figures obtained for 6*ab*, 3, 5*bc*, 8*c*, and 9 as representing the true minima for the entire movement of each tendril, we find the average temperature at which these movements occurred to have been 22·9° C., while the average temperature for the whole thirteen was found to be 25·8° C. The remaining seven movements of greater rapidity were found under the influence of an average temperature of 28·2° C. The following table will show the relation between temperature and rate of movement as just explained:

	No. of movement.	Mean temp.
Maximum movements	13	26·5° C.
Minimum "	13	25·8
Max. movements, (*a*) rapid	6	27·2
" " (*b*) slow	7	24·8
Min. " (*a*) slow	6	22·9
" " (*b*) rapid	7	28·2

With reference to conditions of humidity, it is found that tendrils 6*ab* and 1 gave their minima of movement during pleasant weather, while the plant was apparently in an active condition. The rates per minute were, 0·047, and 0·21^{cm} respectively. Tendril 7*b*, 9, 5*bc*, and 3 gave 0·08, 0·02, 0·043, and 0·013^{cm} respectively during a time of great moisture, and even rain. 8*c* gave 0·025^{cm} during the time of a heavy fog and cold, east wind. The remainder, 4, 7*a*, 2, 8*b*, 8*b*, and 5*a* gave, respectively, 0·031, 0·053, 0·18, 0·10, 0·166, and 0·13^{cm}, at times when transpiration was excessive, as shown by the drooping leaves and terminals, and always during a very bright sun.

Dextrorse and Sinistrorse movements.—The circumnutation of the tendril tip may commence in a direction with the sun or the reverse. Movement in either direction is by no means continued during the entire period of activity. Motion in one direction may soon be succeeded by movement in the opposite direction, one alternating with the other constantly. The dextrorse motion for all the observations taken aggregated 1622·10^{cm}. The sinistrorse amounted to 1400·95^{cm}; and the ratio of one to the other was, therefore, as 1 : 0·86. We see in this a very striking approach to equality in the two movements.

Terminal Bud.

In the terminal bud we have to deal with a movement entirely independent of the irritation of contact, but accompanying a rapidly elongating axis which develops leaves and flowers, as well as tendrils, first upon one side and then upon the other at alternating nodes.

The greatest movement occurred just before noon, but under conditions of great humidity. The least movement took place at night, also under conditions of great humidity. In either case there was nothing to indicate other than a normal condition of the plant. As in the tendril, we here notice a movement to the right and left, the latter being exceeded by the former by 23·30^{cm}. There is in this a very evident tendency to excess of dextrorse movement, but it is a fair question, to be decided only by more extended observations, if there is not or should not be as great equality here as in the movement of the tendril. In the growth of the vine, as well as of the squash, we have in the results obtained still further proof of the influence of meteorological conditions, as already shown.

[To be continued.]

ART. X.—*A Theorem of Maximum Dissipativity;* by GEORGE F. BECKER.

THE proposition which I desire to prove in the following pages is, in general terms, that in all moving systems there is a constant tendency to motions of shorter period, and that, if there is a sufficient difference between the periods compared, this tendency is always a maximum, so that all natural phenomena occur in such a way as to convert the greatest possible quantity of the energy of sensible motion into heat, or the greatest possible quantity of heat into light, etc., in a given time, provided that the interval of time considered exceeds a certain fraction of the period of the most rapidly moving particles of the system.

The simplest case of motion which can be selected for examination is that of a particle describing a path which returns upon itself. In any actual system, such a movement must be a "stable"* one. In a very important class of such movements, there is a position of closest approach to a fixed center and a position of greatest departure from it corresponding to the perihelion and aphelion of planetary motion, and in such cases the symmetry with reference to an axis shows that the "action" between these points must be the same in either direction. The nature of these cases indicates the investigation of half the action for an entire recurrent path.

If an actual, recurrent, stable path is compared with that which would result from an infinitesimal conservative disturbance of the same movement, it appears that the distance between the points of intersection is infinite compared with the perpendicular distance which separates the paths at any intermediate position, and at such a position the paths are infinitely nearly parallel. It is easy to show that lines perpendicular to the two paths intercept arcs on which the action is equal. If ρ is the radius of curvature at any point on one of the curves, $d\vartheta$ the angle which tangents taken at an interval of time dt make with one another, ds the arc described in this time, and if the subscript numeral $_1$ indicates the corresponding quantities for the other path,

$$\rho^2 d\vartheta = \rho_1^2 d\vartheta + \rho_1 d\vartheta \delta\rho;$$

for the curves being parallel have the same center of curvature.

* The motion of a system is stable if after any infinitely small disturbance unaccompanied by a change of total energy, it returns to some configuration belonging to the undisturbed path after a finite time and without more than an infinitesimal digression.

The last term in this equation is infinitesimal compared with the other terms and may be neglected. Hence

$$\frac{\rho d\vartheta}{\rho_1 d\vartheta} = \frac{ds}{ds_1} = \frac{\rho_1}{\rho}.$$

Let $\varkappa$ and $\varkappa_1$ be arcs of the curves on which the action is the same, so that $\varkappa\nu = \varkappa_1\nu_1$. Then since in general $\nu_1 dt = ds_1$ and $\nu dt = ds$, the velocity being represented by ν,

$$\frac{\varkappa_1}{\varkappa} = \frac{\nu}{\nu_1} = \frac{ds}{ds_1} = \frac{\rho_1}{\rho}.$$

That is to say, the radii of curvature at the extremities of the arc ds, or, more generally, perpendiculars to the two curves at the extremities of this arc, intercept arcs on the two curves on which the action is the same. It evidently follows that any two lines perpendicular to the two curves intercept arcs on which the action is the same. A more general proposition embracing this is one of the immediate deductions from Hamilton's principle of varying action.*

The action on any natural path is a minimum provided that the path is sufficiently short, but it is clear, from the last paragraph, that perpendiculars to the undisturbed path and the disturbed path at their points of intersection cut both paths, and that the action is consequently the same on each between the same initial and final positions. It can, therefore, be a true minimum on neither. The action, consequently, cannot be a minimum for a distance greater than that between these points of intersection. These points are called conjugate kinetic foci by Messrs. Thomson and Tait, who give propositions embracing those just stated, but reached by a different method; and who also show that while the action from a given configuration up to the first kinetic focus is always a minimum, it may cease to be the least possible before a kinetic focus is reached.† The variation of the action always vanishes, however, and when the action ceases to be a minimum it must become a maximum or a minimax.

If the path which a particle pursues returns upon itself and if the motion is stable, a kinetic focus conjugate to the initial point usually occurs at the completion of the circuit, coinciding in position with the starting point. Even when this is not the case, however, the action for an entire circuit is the same on the disturbed path as on the undisturbed path. That it is the same up to the last kinetic focus before the circuit is complete is evident. The starting point may be arbitrarily chosen and may therefore be taken at a point where the movement is perpendicular to the line of force. This line then cuts the dis-

* Thomson and Tait, Nat. Phil., § 332. † Nat. Phil., § 358, et seq.

turbed and undisturbed paths at the end of the circuit at right angles, and the action from the last focus to this line on each path is consequently the same.

Whatever the recurrent path of a particle may be, the action upon it will be the same as it would be on a circle of appropriate diameter upon which the particle should move at its mean velocity, completing the circumference in the same time which it occupies on the real path. This condition of the equality of time implies that, if $d\vartheta$ is the elementary angle which the radius of the circle makes with a fixed radius, $d\vartheta = dt$. If the mean velocity of the particle is u, the elementary circular arc is $udt = rd\vartheta$ and consequently $u = r$. Now the area of the circle is

$$\int_{t_1}^{t_1} \frac{r^2 d\vartheta}{2} = \int_{t_0}^{t_1} \frac{u^2 dt}{2} = \int_{t_0}^{t_1} \mathrm{T} dt,$$

T being the kinetic energy of the particle in its real path per unit of mass; the area of the circle is therefore half the action of the particle per unit of mass for an entire circuit. The ratio of the area to the circumference of a circle is of course the greatest possible. This ratio is $\frac{r}{2} = \frac{u}{2}$ and if the length of the circular path is regarded as the independent variable and as a given constant, say s,

$$\frac{su}{2} = \int_{t_0}^{t_1} \mathrm{T} dt = \max.$$

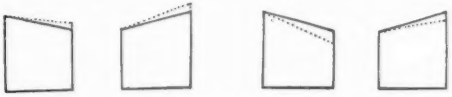
In comparing the mean velocity, the corresponding path, and the product, or the action, one or other, must be considered as given, and the conclusion that one-half the action for an entire circuit is the greatest possible is therefore entirely general.

In cases where the disturbed path returns to the same starting point as the undisturbed path, the action for an entire circuit cannot be an absolute maximum, because the action is the same on various paths between the same terminal configurations, but a proof independent of that in the last paragraph can be given that the action will differ infinitely little from an absolute maximum. Any circuit must be reversible, or the action must be the same in whichever direction the particle traverses the path. As has been shown, the action for an entire circuit is constant and the action for an infinitesimal movement is the least possible. The action from the starting point over the real path, back to a position infinitely near the starting point, is therefore a constant minus a quantity which is the least possible, and is therefore the greatest possible. It also differs infinitely little from the action for an entire circuit.

The theorem of greatest action admits of a further important extension. If we suppose a material point revovling about an attracting center and if, during the revolution, the position of the center of attraction is suddenly changed without altering its distance from the material point, this will immediately begin a new orbit without change in its total energy and the action on the new orbit will be the same as on the old one. The path, however, will not in this case return upon itself. By pursuing this train of reasoning it becomes clear that the action becomes an absolute maximum twice in every period for which the integral curvature amounts to 360° and at the expiration of which the original velocity is recovered. In certain symmetrical cases of motion a starting point may be so selected that the action becomes an absolute maximum once in every 180° of integral curvature. The interposition of a straight path upon which there is no change in kinetic energy, between two arcs, affects the proposition only by lengthening the period between successive maxima.

The two most important cases of motion for the present discussion are that of a particle of an elastic solid which is in vibration and that of a gas molecule in a confined space. In the former the particle vibrates on some stable curvilinear path about a position of equilibrium; for it is well known that a simple rectilinear vibration is an unstable motion which must pass over into an orbit or circuit when disturbed never so little. A gas molecule also pursues a stable path, for if it is rebounding against parallel walls and traversing a zig-zag course in a given plane, and if the angle is changed by an infinitesimal quantity, the disturbed path cuts the undisturbed one at finite intervals and without more than an infinitesimal digression. It is clear from what precedes that the action in both these cases becomes the greatest possible twice for every complete change of direction of 360° accompanied by the resumption of the original velocity.

The meaning of the statement that the action of a particle or a system is a maximum or a minimum for a given period is most readily appreciated geometrically. A natural motion may be supposed to begin with the same energy as a guided motion at any instant of time. Then if we represent the value of the energy of the real motion by a full line and that of the guided



motion by a dotted line, the abscissa representing the time, as in the accompanying diagrams, it is clear that the statement

that the action for a natural motion is a minimum for a given period means, that the average rate at which the kinetic energy has decreased is a maximum or that the average rate at which the kinetic energy has increased is a minimum. The assertion that the action is a maximum means that for the given period the kinetic energy has decreased as slowly or increased as rapidly as possible.

There is every reason to suppose that every natural system is conservative and that there is no natural system in which movements of various periods do not go on simultaneously. To take a simple illustration, it is impossible to vibrate an open string without exciting harmonics as well as the fundamental tone. If there is but one sensible or molar movement in a system, there is at least friction and therefore molecular motion. If we consider an open string for a period equal to that which elapses between the initial movement and that at which the fundamental movement is about to reach its first kinetic focus, it is clear that all the harmonic vibrations must have passed their first kinetic foci. The action of the fundamental motion up to this time will be a minimum and that of the other motions for the same time will be a maximum or minimax. Of the total energy of the system, then, the fundamental motion has a minimum portion and the harmonic motion a maximum or a minimax. If the fundamental motion is compared with one of the higher harmonics it is clear that the order of the latter will be a very moderate one when its action will have reached its period of absolute maximum, while the action of the fundamental vibration is still the least possible. *A fortiori* must this be the case when molar motions are compared with molecular motions or heat-giving vibrations with those which yield light.

It might be objected that since the total energy of the graver vibrations in this instance, or of any corresponding movement in any other instance, does not remain constant, the principles of the action of a conservative system are inapplicable to it. But in the first place if there is a great difference between the periods of the motions compared, the energy of the motion of longer period may be considered as constant for the time of the shorter vibration, and this assumption is commonly made in discussing simultaneous molar and molecular motions. Furthermore, if the periods are not very diverse, the movement of longer period may be reduced to the consideration of a conservative motion by supposing the energy withdrawn from it to be potentialized. For the problem in hand this treatment appears to be something more than a method of approximation; for it is well known that every complex vibratory movement may be resolved into simple vibrations. At the

extreme configurations of any simple vibration, the energy of the simple movement is entirely potentialized. The energy which is transferred from the motion of longer period to that of shorter duration may therefore be regarded as having passed through the state of potential energy. Herein appears to lie the justification of the ordinary method of treating expended energy as if it were permanently potentialized.

In any case of motion involving a variety of periods, then, if an interval of time just less than that which elapses between the occurrence of kinetic foci of the slowest motion is considered, the kinetic energy of this motion will have decreased at a maximum average rate or increased at a minimum average rate, while for the quicker movements the decrease will not be a maximum nor the increase a minimum. Hence in any case there is a tendency of the total energy to the movement of shortest period, and this tendency will be the greatest possible when the particles which vibrate most rapidly expend half the action of the entire circuit while the action of the slowest movement is still the least possible. In favorable cases the difference of period required to develop the greatest possible tendency to the motion of shorter period would be extremely slight, a mere fraction of the period of either movement. It appears to need no demonstration that no sensible movement can cease to be one of least possible action in a time less than the period of vibration of a particle the movements of which are manifested as heat. A diversity of the same order exists between the light-giving and the heat-giving vibrations as between the latter and sensible motion and of course a similar conclusion applies to them. The theorem propounded at the beginning of this essay thus appears to be demonstrated.

It follows immediately that the higher forms of energy can be produced from the lower, or motions of longer period from those of shorter period, only on condition that the sum of the transformations of the system is equivalent to a degradation, a result nearly identical with one of the chief deductions from the second law of thermodynamics.

San Francisco Office of the U. S. Geol. Survey, Oct. 1885.

ART. XI.—*A new Law of Thermo-Chemistry;* by GEORGE F. BECKER.

IN the course of an unpublished chemical investigation of a process involving nearly a hundred reactions, I adopted, as a guide to experiment and as a check upon the conclusions, M.

Berthelot's famous thermochemical law,* with extremely satisfactory results.

This law, the experimental proof of which is very convincing, applies only to the final molecular configuration of given substances, however, and gives no information as to the series of transformations which they undergo before reaching a condition of stable chemical equilibrium. But in many of the chemical processes of nature, and in some technical operations, the reactions are interrupted before the final result is attained. In all cases it is a matter of great scientific interest to know the law governing the actual series of transformations from the initial to the final condition of a mixture of substance, between which reaction takes place.

In the course of the experiments referred to, it appeared to me that the *rate* at which chemical energy is converted into heat by various possible reactions was an important factor in determining the order of their occurrence. But even the determination of the total thermal effects of reactions requires extremely delicate experimentation, elaborate apparatus, and other special facilities. To determine experimentally the rate at which this heat is produced would be a still more serious matter and was quite out of the question with the time and resources at my disposal for this purpose. I therefore undertook to inquire whether, by considering chemical energy as a form of motion, any definite results could be reached as to the rate of evolution of heat. This investigation eventually led to a principle embracing that sought. It appears under the title of a theorem of maximum dissipativity in the preceding article. The chemical interpretation of this principle is as follows: The sum of the chemical and physical transformations in any chemically active system will be such as to convert higher forms of energy into heat, light, etc., at the greatest possible rate, provided that the interval of time for which the comparison is made is a multiple of a certain fraction of the period of the most rapidly moving particles of the system. For all experimental and for most theoretical purposes this is equivalent to the statement that the transformations will be such as to evolve heat, light, etc., at the highest possible rate.

This law evidently includes M. Berthelot's, of which the principle of maximum dissipativity affords a rigid demonstration. The tendency to the conservation of molecular type which M. Berthelot has observed in complex transformations† also seems a natural though not rigidly demonstrated conse-

* Principe du travail maximum.—Tout changement chimique accomplé sans intervention d'une énergie étrangère tend vers la production du corps ou du système de corps qui dégage le plus de chaleur. Mécanique Chim., vol. i, p. xxix.

† Méc. Chim., vol. ii, p. 471.

quence, for it can hardly be doubted that a simple substitution in an existing compound will, as a rule, take place more rapidly than a fundamental re-arrangement of atoms.

I shall have occasion hereafter to call attention to instances in which, as nearly as can be ascertained without exact determinations of rate, the order of ordinary laboratory reactions conforms to the law here announced. I desire, however, to point out without delay its applicability to a problem of geological chemistry, in which exact and direct experimentation is almost or quite impossible, viz: the order of the genetic succession of minerals in massive rocks. This is a subject of the greatest importance to rock classification and to the whole science of lithology. It is also one in which little or no advance has been made.

No *a priori* guess could be more natural than that the order of succession of minerals in eruptive rocks is that of their fusibility. Indeed, this corresponds closely to the old empirical (and incorrect) rule of chemistry, according to which precipitation takes place whenever an insoluble compound would result from any re-arrangement of molecules. Nothing is more easily confuted, however, than this hypothesis of genetic succession, if rigidly interpreted, since magnetite, for instance, is among the first and among the last minerals to form in several eruptive rocks. Bunsen, too, has shown that the temperature at which an isolated body solidifies is never that at which it separates in the solid state from its solutions.* This fact does not appear to me to show that the order of succession has no connection with the fusibility, as is sometimes stated,† but only that if such a connection exists, it is not an entirely simple one. There are coincidences between the order of succession and the order of fusibility of the mineral species composing massive rocks which it is scarcely possible to regard as accidental. Thus zircon and olivine are among the first minerals to solidify, and their only common characteristic appears to be a high degree of infusibility. The highly refractory quartz, too, is an early mineral in the quartzose porphyries, and sometimes, also, in granite. Messrs. Fouqué and Michel-Lévy were, I believe, the first to show‡ that in the following triclinic feldspar series; anorthite, labradorite, oligoclase; the crystals of primary consolidation almost always precede the crystals of secondary consolidation. They have also shown§ that this is the order of the fusibility of these minerals, while Professor Szabo finds that bytownite and andesine occupy a position in the scale of fusibility similar to that which they occupy in the scheme of chemical composition.

* Zschr. Geol. Ges., 1861.
† Roth, Allgemeine u. chem. Geol., vol. ii, p. 48.
‡ Min. microgr.
§ Comptes Rend., 1878.

The hypothesis that the order of genetic succession is that of increasing acidity has been advocated, I believe, only for granitic rocks. Even for these it is not rigidly true. The order in which the feldspars appear in volcanic rocks, however, is also one of increasing acidity, as well as of increasing fusibility. Such relations between chemical composition and fusibility are of course extremely frequent, especially among organic compounds. Messrs. Fouqué and Michel-Lévy also found albite more fusible than labradorite and less so than anorthite. Those who regard the plagioclases as isomorphous mixtures of anorthite and albite must, therefore, consider oligoclase as the most fusible mixture of the two, while it also appears to be commonly the last feldspar to crystallize. A similar maximum fusibility is known to exist in other series. Thus the fundamental slag of iron blast furnace practice is an exact bisilicate of the form $4CaSiO_3+AlSi_3O_9$. This is the most fusible compound of these ingredients, any alteration in the acidity or in the ratio of the bases rendering it more difficult of fusion. Oligoclase contains more aluminium than the slag, but also sodium.

It thus appears that while the chemical composition and the fusibility of the rock forming minerals are most intimately connected, neither of these properties affords an adequate explanation of the order of genetic succession, nor does any known combination of them explain the facts. That the fusibility at least is not without effect upon the order of succession seems highly probable, but, if so, there are other concomitant influences which very materially modify the results.

If the changes which occur in cooling eruptive magmas obey the laws of thermo-chemistry, the somewhat confused relations actually observed between genetic succession, fusibility and acidity are just such as might be expected in advance. There is every theoretical and experimental reason to suppose that the fluid eruptive magma consists of one or more compounds differing essentially from the minerals eventually formed from it. In cooling it must therefore undergo a series of chemical and physical changes. The formation of any new stable chemical compound, whether fluid or solid, in the mass converts other forms of energy into heat; but, at the same time, the subtraction of any such group of molecules from the previously existing combination alters the chemical constitution of the residue. It is quite conceivable that the change in the residue should involve either an absorption or a liberation of heat, but if the former and if this were to exceed the positive thermal effect of the supposed stable compound, the whole operation would be impossible. In general, if no physical change accompanies the alteration of chemical configuration, that chemical change and that only will take place through which heat is liberated most rapidly.

It is not sufficient, however, to consider the chemical transformations by themselves, for these are in general accompanied by physical alterations in the mass. Much the most important of these is solidification, which is always accompanied by a liberation of heat.* Now the amount of heat evolved by the solidification of compounds is of the same order as the thermal effect of chemical combination. Since therefore the sum of the chemical and physical changes must be such as to develop the maximum amount of heat per second, let us say, the fact that heat is liberated by solidification establishes a distinct tendency to the formation of solid precipitates; but this tendency is only operative on condition that by no other transformation can heat be more rapidly liberated.

In view of these considerations it seems almost certain that the order of genetic succession of minerals will sometimes follow the order of separate solidification, but that in a greater or smaller proportion of cases there will be essential differences between the two orders. Thus there is no difficulty in understanding that at a certain early stage in the cooling of an eruptive mass, the rapidity of the evolution of heat may be promoted by a separation of a portion of the iron as magnetite, while the separation of the entire mass of this mineral at this stage would be incompatible with the most rapid possible evolution of heat by the entire simultaneous chemical and physical changes then progressing. So also if two magmas of similar qualitative but different quantitative compositions are compared, it does not seem remarkable from a thermo-chemical standpoint that augite should separate before labradorite in the one and labradorite before augite in the other (andesite and basalt).

In one sense the above discussion is of little value to lithology. The new law of thermo-chemistry does not enable one to state what will be the order of genetic succession of minerals under a given set of chemical and physical conditions. This is because the total thermal effect of many of the rock-forming minerals is unknown, while, so far as I am aware, the rate at which reactions evolve heat has not yet been studied by exact methods. But the law at least explains why neither fusibility nor basicity obtains complete control of the process and how it may happen that the order of succession which prevails in one set of cases may be reversed in another. The new principle governs the genetic succession of minerals in eruptive rocks, but the constants of the equation in which it may

*Solidification of course takes place at a lower temperature than fusion. This appears to be a theoretical necessity, for if any small fraction of a mass were to solidify at the melting point, the heat evolved by the act of solidification would raise the surrounding temperature above the melting point and the solid particle would melt again.

be expressed remain to be determined. The number of these constants will doubtless be diminished by future generalizations and the application to lithology thereby simplified.

Since the rate at which heat is evolved in a solidifying lava is the greatest possible, the rate at which it cools, other things being equal, must be a minimum. This fact must have an important influence on the flow of eruptive rocks and probably accounts in part for the power which they possess of penetrating the tiniest cracks as dikes.

San Francisco Office U. S. Geol. Survey, Nov., 1885.

ART. XII.—*Recent Explorations in the Wappinger Valley Limestone of Dutchess County, N. Y.;* by WILLIAM B. DWIGHT.

No. 5.—*Discovery of fossiliferous Potsdam Strata at Poughkeepsie, N. Y.* (Illustrated by a map, Plate VI.)*

THE presence of rocks of the Potsdam group in association with the limestones and shales of Dutchess County, N. Y., has long been suspected on stratigraphic grounds, but until the present time this fact has never been proved by positive paleontological evidence.

At the bases of Fishkill and Stissing Mountains, a thick stratum of quartzyte is found between the underlying Archean of those mountains, and the overlying limestones, now known to be respectively Calciferous and Trenton. This quartzyte shows planes of stratification, and is conformable to the overlying strata of limestone. Obviously, by its stratigraphic position, it appears to represent the Potsdam group, and this assignment has been made for it, in the localities mentioned, by Professor Mather, Professor J. D. Dana and others.

Notwithstanding that considerable search has been made, no fossils have yet been found in this quartzyte stratum, by which this reasonable hypothesis might be established. I am not aware that any geologist has heretofore found reason to suspect the presence of a Primordial stratum among the limestones of the region, and certainly I have had no such expectations myself. The observations made during the last few years in the Wappinger Valley (or "Barnegat") limestones, have definitely proved them to be composed extensively and continuously of conformable strata of the Calciferous and Trenton groups. In carrying out the work, in which I have for several years been engaged, of preparing a detailed stratigraphical chart, on April 25th of the present year, to my great surprise,

* Read before the American Association for the Advancement of Science, at Ann Arbor.

I struck a ledge of rock in the Wappinger Valley limestone belt, which proved rich in Potsdam fossils.

This remarkable locality is on an estate owned by Mr. Albert K. Smiley, proprietor of the Lake Mohonk House. It is in the outskirts of the city of Poughkeepsie, to the southeast. It is about one mile southwest of Vassar College, 850 feet south of the southwest corner of the Driving Park on Hooker avenue, and about 2200 feet west of the road which passes south along the east side of the same.

The Potsdam rocks are found in a series of low hills or ridges trending northeasterly and southwesterly in parallel lines. The most interesting paleontological features appear to be concentrated in a ridge lying at the northeast corner of the group (Hill A, Plate VI). This is situated immediately to the southwest of Smiley's detached barn, which is itself south of the southwest corner of the Driving Park. This hill is about 300 feet wide and 1400 feet long; it is mostly covered with soil, the rock cropping out on each side, but chiefly on the east, in a few narrow, quite inconspicuous ledges; it would never have attracted my attention but for its occurring within the range of a systematic survey.

Lithologically this Potsdam rock is exceedingly variable, and all the varieties described occur within the small compass of a few acres of ground. It is everywhere (so far as already examined) calcareous, all its varieties effervescing with acids. It is also everywhere more or less arenaceous; often conspicuously such. Large portions of it are a tough, compact limestone, often quite dark, and frequently filled with a conspicuous fucoid-like tracery; the weathered surfaces are often rough with sand-grains. This variety passes into one which differs chiefly in being fissile into more or less thin slabs; this variety often alternates with layers of exceedingly thin and friable shale, the folia of which are covered with loose sand as they decompose.

The rock also passes on the one hand into argillaceous varieties represented by a smooth, fine-grained, massive argillaceous limestone well exhibited on the west side of the main fossiliferous hill; and represented also by a very fissile and smooth calcareous shale, well shown in a hill (E) which is a continuation, in the second field south, of the above-mentioned hill. Although nearly as fissile, this variety differs essentially in appearance from the closely adjoining Hudson River shales, which are much darker, and more glazed or shining on their surfaces. On the other hand, this Potsdam rock passes into a very solid, massive quartzyte, the fine sand-grains of which are everywhere in absolute contact, so that in appearance it is only a grade less compact than the quartzyte of Stissing Mountain;

but the minute interstices are occupied by calcareous material, so that the rock effervesces a little under acids.

In many places, again, the material takes the form of brecciated conglomerate; this is well shown in the western Potsdam hill at the northern extremity of the tract under consideration (Hill B), and its extension south into the next field (Hill D); also in the western marginal Potsdam ridge just south of T. A. Hinkle's house in the next field.

The southeastern extremity or fork of the main fossiliferous hill (A) is a solid mass of peculiar oölyte, made up of spherules which are simply aggregations of rhomboidal calcite crystals imbedded in the interstitial mass of quartzyte or calcareous quartzyte. I have found pebbles of this peculiar oölyte in the conglomerate above mentioned in the ridges of the western margin, suggesting a later date of deposition for the latter. In many places these Potsdam rocks exhibit very distinctly oblique lamination.

The strike and the dip are quite variable. The most general strike of these Primordial strata appears to be about N. 21 E. (true), and the most general dip about 55° easterly. Some further statements as to local variations will be given subsequently.

In order to determine the true stratigraphic relations of these Potsdam and related strata, I have made a special detailed examination of a district covering about a mile and a half square in the vicinity of this locality, and embracing about a mile and a quarter of longitudinal extension in the direction of the strike. This district is mapped in Plate VI.

This Potsdam rock is one of the component members of the most western, and by far the broadest of three parallel belts of the Wappinger Valley limestones, which, in this vicinity, rise between the Hudson River shales. In general, all these limestones and shales lie in a series of abraded folds, having usually a conformable strike of from N. 20° E. to N. 30° E. These folds are closely compressed, and pushed over to the west, so that the earlier limestones usually overlie by inversion the later shales lying to the west of them.

The particular belt of limestone which stretches southwest from the Driving Park is about 3500 feet in width at its northern extremity, and about 6000 feet wide at the southern portion of the limited district now under consideration. This southern transverse line of 6000 feet passes through the middle of the estate of W. S. Johnston on the Albany Post Road.

This belt terminates toward the north, quite abruptly, along an almost straight line which cuts it apparently at a right angle to the strike. This line runs along the southern margin of the Driving Park, continues east through the fields parallel to Hooker avenue till it meets the Hudson River shale in the

meadows of Casper Creek. Immediately north of the Driving Park, in fields on the north side of Hooker avenue (locality O, plate VI), in place of limestone there are hills of Hudson River shale, and this same rock crops out along Hooker avenue to the west all the way to Casper Creek and beyond. From this line these shales continue unbroken many miles to the north beyond Hyde Park. Along this northeasterly and southwesterly line, the intervening space between the outcrops of shale on the north and of limestones on the south consists of a mostly level strip of drift having bogs and springs along its southern edge. Evidently this is a line of fault, across the strike, between the Hudson River shales on the north and the Potsdam, with its associated Calciferous and Trenton, on the south. This trough, cut through the hilly ridges, is a conspicuous feature in the local landscape. It is made available for traffic by the avenue that passes through it obliquely into the city; it furnishes the long and smooth plat (mostly underlain by the shales) which constitutes the Driving Park.

The stratigraphic relations of the western margin of the belt of Potsdam have proved far less obvious than those of its northern extremity. But after a careful detailed inspection of the ground, a correct solution, as I believe, has at last been reached. During the earlier examinations, Calciferous or Trenton strata were naturally looked for, in intervening folds, between the Potsdam and the Hudson River shales to the west. The western hill of conglomerate above mentioned (Hill B) and its southern extensions, were at first taken to be the Trenton coralline conglomerate which occurs abundantly in the vicinity. But on further investigation, two facts were developed which opposed this supposition. The first fact was that the lithological constitution differed entirely from that of the Trenton wholly-calcareous conglomerate, in being highly arenaceous, as also in the entire lack of the microscopic corals which abound in the Trenton. On the other hand, its lithological characters are quite in harmony with those of the adjoining ledges known to be Potsdam.

In the second place, an outcrop of the Hudson River shales was discovered close to the western base of this hill, within a few feet, thus marking the line as the actual western limit of the limestone. This limit is at the most but 300 feet west of the fossiliferous Potsdam strata, a space by no means sufficient to allow the presence of Calciferous and Trenton strata of the usual thickness exhibited in the region. A further study of all the phenomena makes it quite certain that the Potsdam extends to the western margin of this belt of limestone, in its entire southern extension through the district examined. This limestone margin (as traced from the north) is broken by three

or four jogs, as the belt widens to the west, until the field next south of T. A. Hinkle's cottage is reached; from that point it is nearly straight. Close to this line, at the distance of a few feet throughout its entire length, there are many outcrops of Hudson River shale which continue west to the Hudson River, unless Utica shales may occur at some points. The shales are in many places separated from the Potsdam limestone by lines of springs and ponds, or by dry gullies. From the extreme northern end, the plane of contact is marked by a line of ponds nearly to Hinkle's house. Close to this house, to the west of it, there is a deep gully, with the limestone on which the house stands, on the east, and the shales, standing nearly vertical in a bold exposure, on the west. This gully continues to mark the line to the southwest as far as the turn in the Ferris road, beyond which the demarcation is produced by a different but no less striking plan; for south of this point the limestone remains a high conspicuous ridge, abruptly steep on the western side, while the shales, mostly covered by drift, form a level plain at its base.

These facts make it evident that there is also a line of fault between the Potsdam and the Hudson River shales at the western margin of the limestone belt, more or less parallel to the strike. The general direction of this line of fault is about N. 40° E. The Potsdam strata near the line of contact are generally deflected in such a way as to have less easting in the strike, which is in such places from N. 4° E. to N. 11° E. Thus at the extreme north end of the main fossiliferous hill (A) the strike varies between the limits just given, while the dip becomes as low as 20°. At the hill of calcareous quartzyte in the third field south of the Driving Park (Hill F) the strike is in some places N. 11° E., and the dip 35°.

On the other hand, the Hudson River shales incline to acquire more easting in the strike, in the vicinity of the plane of contact. In such cases they have quite frequently a strike of N. 46° E. (their general strike in the vicinity being about N. 31° E.). They also, in such positions, are often found inclined at a very high angle. These phenomena seem to indicate considerable friction by a lateral motion in a northeasterly and southwesterly direction, as well as in the upward motion, at the time of the uplift of the Potsdam. This fault is the more interesting, because it is evidently related to the great fault described by Sir William Logan and Professor James Hall as extending from Quebec to the Hudson River near Rhinebeck. If, as has been suggested by Professor J. D. Dana, this should more properly be regarded as a series of more or less parallel faults, the present one would constitute the most southern one of the series yet described.

With regard to the eastern boundary line of this strip of Potsdam nothing definite can be determined from present data. There are no fossils to indicate the points of transition to the Calciferous and Trenton, which doubtless lie in abundant development to the east. The uncertainty is increased by the fact that a great part of the rock is deeply buried under drift. Thus, at the northern extremity, east of the fossiliferous Potsdam, after about six hundred feet of strata (which are probably to some extent at least of the same group), the limestone entirely disappears under a large hill of more than fifty feet depth of drift in A. Vanderberg's farm. (This hill is so covered with debris of Hudson River shale that one might readily suppose it to be the rock in place.) The limestone does not reappear until the southeastern base of Richmond Hill on Casper Creek is reached. That this eastern margin of the belt is Trenton is proved by a distinct outcrop of fossiliferous Trenton filled with *Solenopora compacta* ("*Chætetes compacta*") appearing in a small patch on a hillside 520 feet from the house of R. J. Kimlin on a course of N. 101° E. The Calciferous is doubtless extensively represented between the Trenton and the Potsdam, but this has not been paleontologically determined.

In view of the above facts, I can make only the general statement that the minimum width of the belt of Potsdam strata, measured on the surface of the ground, is somewhat over 600 feet. If, as seems probable, there is at least one compressed fold, the actual thickness of the deposit must be over 300 feet.

It is my present impression that the Potsdam folds occupy, as indicated on the accompanying map, a strip of about 1400 feet in width, and that the high and continuous limestone hill (K) on the east of this strip may form the western margin of the Calciferous strata. In this case the small quarry in the field of W. S. Johnston, at the southeastern portion of the district (H), would be near the eastern edge of the Potsdam. This view is strengthened by the fact that lines of ponds and springs exist conspicuously along the base of this long eastern hill, indicating a possible break or slip between strata along this line. But as fossils have not yet been found in the last mentioned hill, nothing more positive can be asserted in this connection at present.

A brief description may now be given of the paleontological features of these strata.

In the fossiliferous hill above described (A), organic remains are found chiefly on the eastern side near the summit in the southern half, though not in the oölytic portion. They occur both in the solid fissile limestone, and in thin layers of shale

associated with it. The fossils are present in considerable numbers, but so much scattered through the rock that large masses must be broken up to obtain a few organisms.

I have also found a few specimens of Lingulepis in the extension of the western fork of this hill in the second and third fields beyond, where it becomes a blue calcareous shale (E).

No fossils have yet appeared south of Mr. Smiley's property, that is, south of the fourth field from the Driving Park, except some Stromatoporoid forms which are not infrequent throughout the Potsdam strata. From these localities I have already collected over 500 fossils; some of these are in a perfect state of preservation, while many are in a very imperfect and fragmentary condition. There is no doubt whatever as to the presence among them of several well-known and well-marked Potsdam fossils, while the whole group appears to belong to that geological horizon. Since, in my explorations among these limestones during seven years, all of the abundant fossils found have indicated the presence of either the Calciferous or of the Trenton formations alone, I have not failed to consider the question carefully whether the present fossils, though of a Potsdam type, may not after all exist here in Calciferous strata. But I have found no facts to favor the latter supposition. The rock is lithologically considerably different from any known fossil-bearing Calciferous in Dutchess County. The fossils are all of the type so well known in the Potsdam rocks of New York State and of Wisconsin, while no single Trenton or Calciferous fossil of the vicinity or of any locality, has appeared among the hundreds here collected.

These fossils will require a very careful study for a full determination as to the number of genera and species. The following preliminary statement will indicate their nature in general.

1. *Lingulepis pinniformis;* several specimens of both valves, some of which are quite perfect.
2. *Lingulepis minima;* many specimens of both valves.
3. *Lingulepis acuminata*, probably; several good specimens.
4. *Obolella* (*Lingulella*) *prima;* several specimens.
5. *Obolella;* a minute species resembling "*Nana;*" one or two specimens.
6. *Platyceras;* undescribed species; one or two.
7. Remains of small encrinal columns; several.
8. *Ptychoparia* (*Conocephalites*); n. sp. resembling *Iowensis*, but possessing an occipital spine; several glabellas and pygidia.
9. *Dicellocephalus;* two or more species; undetermined; numerous specimens.
10. *Ptychaspis;* one or more undetermined species; several specimens.
11. *Stromatocerium?* undetermined; abundant.

The more abundant of these fossils are the *L. minima*, whose fragments are thickly scattered through some portions of the shaly limestone, and next the movable cheeks of trilobites.

It will be observed, as has been suggested to me by Mr. R. P. Whitfield, that the fauna of this locality forms a connecting link between the known fossils of the Appalachian region and those of the Western States. Thus with the *Lingulepis minima* and *L. acuminata* of the New York Potsdam is found the *Lingulepis pinniformis* of Wisconsin and other western localities.

It may also be remarked that the fauna of this Poughkeepsie locality, as far as at present developed, is quite distinct from that of the Potsdam strata recently discovered by Mr. S. W. Ford at Schodack Landing and other places in the town of Stuyvesant, N. Y. From these localities, lying about fifty miles north of Poughkeepsie, Mr. Ford reports (this Journal, July, 1884) the following eleven species: *Paleophycus incipiens*, *Obolella crassa*, *Stenotheca rugosa*, *Hyolithes Americanus*, *H. impar*, *Hyolithellus micans*, *Microdiscus lobatus*, *M. speciosus*, *Conocoryphe trilineata*, *Olenellus asaphoides*, and *Fordilla Troyensis*.

No one of the above list has been found at Poughkeepsie; the distinctive character of the two faunæ is evident, the latter apparently representing an earlier stage of life.

The discovery of the presence of fossiliferous Primordial rocks among the Wappinger Valley limestones, while it adds an extremely interesting feature to the geology of the region, contributes another complication to the difficult task of mastering the stratigraphy of Dutchess County.

Vassar College, Poughkeepsie, N. Y., June 25, 1885.

NOTE.—Since the above paper was written I have conducted these researches further, and have traced the continuation southerly of the fault between the Potsdam and Hudson River shale to the bank of the Hudson River. This line, which had been traced previously only into W. S. Johnston's farm, has been found to continue, well marked as before by ponds and gullies, in a straight line till it crosses the Albany post road at the corner of the New Hackensack road near School House No. 2. On the west side of the post road it passes straight across R. T. Gill's farm, then crossing the road leading to the Milton Ferry, and striking between the two roads leading in a southwesterly direction to the river. It terminates finally in a high bluff on the river near Mallory's Moulding Sand Dock and about one mile north of Clinton Point post office. Throughout this course the Primordial limestone and the shales show themselves frequently in close proximity in outcrops. In Gill's farm both formations are mostly covered by hills of drift, but on this farm, just north of the Milton Ferry road, both the Potsdam limestone (here as calcareous shale) and the Hudson River shales crop out distinctly. The latter yield at this locality some very excellent and characteristic fossils, as encrinal columns, *Leptæna sericea*, etc. The terminal bluff at the river is composed of *both* formations, the fault running along its summit, but near the northwestern edge. As the extreme southwestern point of the bluff is reached, the line of fault drops down its northwestern side, and the shales at last disappear, leaving the point in possession of the limestone. After careful examination I am satisfied that some, if not all, of the moulding sand is produced by the decomposition of the arenaceous Potsdam. Indeed, the process may now be seen going on

in the layers of the sandy limestone. It is very probable that the Potsdam may now be further traced across the Hudson River somewhere near Marlborough.

In Plate VI will be found a small map showing the entire extent of the fault above described.

It is proper to state here that I have strong reason to suspect the presence of a parallel belt of Potsdam limestone, more than a mile to the east of the present one, in the most eastern of the three belts of limestone. The particular locality which has furnished grounds for the above statement is on the summit of the ridge about half a mile southerly from the mansion on the MacPherson (late Boardman) place. The rock corresponds closely in its lithological characters with that of the Smiley locality. I have found here but a single fossil—about half of one valve of a brachiopod, which as far as it goes corresponds perfectly with *Lingulepis pinniformis*. I believe it to be this fossil, and that consequently the rock is Primordial, but cannot say that the evidence is absolutely conclusive.

EXPLANATION OF PLATE.

A, Hill of fossiliferous Potsdam on Smiley's farm.
B, Hill of Potsdam, partially conglomerate, on Smiley's farm.
D, C, extensions of hill B. D is largely conglomerate.
E, Hill containing much fine-grained, blue, thinly fissile calcareous shale of the Potsdam group: a few specimens of *Lingulepis pinniformis* have been found here.
F, Calcareous quartzyte, Potsdam group.

The lane between the wall and fence just south of the hills E and F is the southern boundary of Mr. Smiley's farm; at present date no Potsdam fossils, except stromatocerium, have been found in this belt south of this line.

G, one of the best localities for inspecting the Potsdam limestone and calcareous shale composing this long hill. Stromatocerium is found here. From the summit of this hill a good view is presented of the wide plain of Hudson River shale which extends westward from its base.
H, a small quarry of arenaceous limestone apparently Potsdam, in the field belonging to W. S. Johnston.
I, a high ridge of light- and dark-colored limestones, well exhibited at the spring here indicated; horizon of the rocks doubtful.
K, outcrops of Hudson River shale at the surface of the ground within a few feet of the Potsdam hill B.
L, small quarry of compact, gritty layers of the Hudson River group, dipping at a low angle.
O, hilly outcrops of Hudson River shale in field north of the driving park.
M, (in small included map), molding sand, and dock.
T, (in small included map), outcrops of fossiliferous Trenton on the eastern margin of this limestone belt.

ART. XIII.—*Wind Action in Maine;* by GEORGE H. STONE.

DRIFTING sands of the ordinary type are very common in Maine, especially in the western half of the State. These sands are partly of marine, partly of fresh-water deposition. All of the large rivers of Maine, except the Penobscot, covered large areas with sand near where they emptied into the sea during the Champlain epoch, the sea of that period being, as is well known, somewhat more than 200 feet above its present level. For various reasons the drift of the Penobscot valley differed considerably from the valley-drift of any other large

stream of New England. The valley of the Androscoggin is preëminent for its sand dunes. One can travel in a carriage along this river from Brunswick to the New Hampshire line at Gilead and hardly be out of sight of drifted sand for an hour at a time. In Wayne, within the last forty years, the sand has drifted eastward from one half a mile to nearly one mile, and up the western slope of a hill 250 feet high, and now is descending the eastern slope. In places the dunes must have traveled two miles or more away from the river valley where they were originally deposited as valley-drift. Often on hill-sides a pine growth is found where one would naturally expect the hard deciduous trees. Investigation shows that drifting dunes have passed over the hill, and have left more or less sand as a covering of the till. The explorer of the drift of Maine soon comes to regard this blown sand as perhaps his most protean adversary, especially when trying to locate the shore line of the Champlain sea. It is not, however, the purpose of the present writing to treat in detail of the ordinary dunes, but to describe two less common phases of wind action.

I. *Till Burrowing.*—Not rarely spots bare of vegetation can be found on hill-sides exposed to high winds. Here during dry days the wind removes the finer parts of the till and drives the gravel back and forth just as happens in Colorado during the dry winter weather. But the rains fall so frequently in Maine, and the ground during the winter is so generally covered with snow, that under ordinary conditions the wind is never able to blow away much of the till in this manner. A few inches is all that I have ever seen thus removed. But along the borders of the drifting sands the case is different, especially near the tops of hills where the till is not kept moist by springs. Here the protecting vegetation has often been destroyed over large areas by the drifting sand, and the rapid evaporation from the sand seems to keep the till dryer than elsewhere. As a result the till is here blown away much more rapidly than usual. Small bluffs are formed, partly owing to the direct effect of the wind in blowing away the finer parts of the till, and partly from the impact of the blowing sand which is near by. A talus composed of the coarser gravel and bowlders of the till is thus left at the base of the cliff and scattered promiscuously over the denuded surface. In this way considerable areas of the till have in some cases been denuded as the drifting sand traveled from place to place. A fine instance of this kind of till-burrowing is found on the top of a hill about one mile northwest of Wayne village. Here, in 1879, the wind had excavated the till to a depth of nearly three feet and the glaciated ledges had been laid bare for a distance of several rods. The glaciated stones of the till retained their scratches in perfect condition,

showing that the process of denudation had been so rapid as not to permit much weathering of the stones or much sand-polishing.

II. *Sand-Carving.*—In Professor C. H. Hitchcock's Report on the Geology of Maine for 1861 (pp. 266–8) reference is made to a peculiar train of bowlders found by Dr. N. T. True at Bethel, Maine, and described by him before the Portland Society of Natural History. A part of Dr. True's description is as follows: "I wish now," says Dr. True, "to call your attention to a collection of bowlders of a peculiar character found in Bethel, in this State. These bowlders are scattered over the surface of the soil for several square miles. On one side may be seen grooves, scratches, strial and polished surfaces. Nothing of this is seen on opposite sides of the same rock. The opposite surface is usually angular, as if it had not been subject to abrasion since its detachment from the parent rock. Frequently, as in the specimens before you, may be seen sharp angles formed by a different presentation to the abrading surface. Sometimes the grooves present an undulating surface as if it had been subjected to a tremulous movement from the impending mass. * * * There is a freshness in their appearance as if they had been grooved yesterday. They present no appearance like rocks on the sea-shore, which have been exposed to the action of water. They are composed of granite, hornblende, and grey-wacke slates." Professor Hitchcock remarks (loc. cit.), "the bowlders in Bethel are very curiously shaped: and it is not easy to say how these shapes were produced." Dr. True sent some of them to President Edward Hitchcock of Amherst, who under date of Jan. 16, 1854, writes: "I am very much puzzled with the specimens. They are different from anything I have seen, and deserve careful study. The grand point of difficulty is to account for the bowlders being held in so many different positions in order to be scratched, or rather grooved, for the striæ are different from those in common rock." Both President Hitchcock and Dr. True thought that the peculiar form of these bowlders was due to iceberg action, a very natural view considering the then prevalent theories as to the origin of the drift.

The writer first studied these bowlders in the field in 1879, when they were pointed out to him by Dr. True himself. At that time, in addition to the characteristic bowlders in the vicinity of Bethel, I found one of precisely the same character in Gilead, also one about a mile east of Gorham, New Hampshire. (Dr. True thought they were only to be found at Bethel.) It will be seen that these localities are all near the Androscoggin river, and but a few miles from the White Mountains. The unusually carved bowlders were all found

on hillsides above the level of the valley-drift and most of them were on the south side of the river on slopes well exposed to the north and northwest winds. In fields and by the road-sides in Bethel, where the bowlders had probably never been disturbed by plowing, I made note of the positions of the polished faces of hundreds of the bowlders. The polished surfaces were turned in every direction, but more faced the west and northwest. Dr. True's observation that one face of these bowlders is usually unpolished was verified, though in one case a bowlder was found polished on all faces. In the majority of cases this unsculptured face was *the lower face.* In the year 1880, I deposited specimens of the Bethel bowlders in the cabinet of the Boston Society of Natural History, and submitted them to several glacialists for examination. But during all of this time none of us obtained any inductive clue to the mystery—the cause of the peculiar carvings. In 1881 I removed to Colorado and for the first time saw in the field the sand-sculptured bowlders so common in the arid regions, and their forms were seen to be the same as those of the Bethel bowlders. Here at last was an opportunity to leave speculation for a valid induction. At once several theories were suggested as accounting for the peculiar shapes of the Bethel bowlders, but it has been necessary to wait for several years in order to determine by observations in the field which one is the true hypothesis. Three of these alternatives are here stated and briefly discussed because they bear on the question of the causes of the shapes of the drift materials, and this is sure to be a pressing and significant question for glacialists to solve.

1. These bowlders may have been sand-carved by the wind in their present positions, and recently. If true, this hypothesis could easily be verified by finding the process now in operation.

2. They may have been sand-carved by the dashing of the rain chiefly. That this is a cause of sand-carving there can be no doubt; but if such extraordinary forms as those at Bethel are due to this cause, then similar surfaces ought to be common everywhere, unless there is something in the Bethel bowlders fitting them to receive or preserve such polishing better than other bowlders. But on the other hand they are only ordinary drift bowlders, representing various common rocks; they are neither harder nor softer than many others, nor can they resist weathering any better. Many of them are of a very feldspathic granite, while in others quartz predominates.

3. They may have been sand-carved by glacial streams. Whenever swift sediment-laden streams impinge obliquely against a rock surface, that surface is carved into tremulous grooves showing many sub-conchoidal depressions very nearly

like the Bethel bowlders under consideration. On the average, the depressions are perhaps shallower in proportion to their breadth when made by water, than when the abrading agent is driven by the wind. This kind of sculpturing I have seen in a great many places both in Colorado and in Maine, almost everywhere, in fact, where the rock does not weather faster than the streams can polish the surface. Fine examples can be seen at the Rumford Falls of the Androscoggin, also at the High Falls of the Saco, near Hiram. Crystalline rocks are more likely to show this kind of eroded surface than sedimentary rocks, unless the latter are very firmly cemented.

So far as my observation goes, sand sculpturing by flowing water only takes place when the water strikes against a surface that is stationary for a considerable time. This is not likely to happen except in case of the solid rock or of bowlders of considerable size. The swiftness of current necessary to produce sand-carving will from time to time roll the smaller stones and bowlders into new positions. The attrition and concussion of the stones against each other so modifies the forms due to the sand and gravel driven by the water that the stones are rounded into pebbles, and do not receive the peculiar conchoidal depressions and tremulous groovings due to pure sand-carving. Thus, for instance, in the beds of the swift streams of the White Mountain region, the fall is often 100 or more feet per mile, and the bowlderets and smaller stones are well rounded like beach or Kame pebbles and cobbles. Some of the Bethel specimens are only two or three inches in diameter, too small to have been sand-carved by water under ordinary conditions. But Bethel was not far from the end of the local Androscoggin glacier, and it may be said that it is possible that the peculiar carvings were due to sediment-bearing sub-glacial streams acting on stones and bowlders which were for a time held fast in the ice. At several points in the Androscoggin valley, between Gorham, N. H., and W. Bethel, Me., I have found surfaces of the solid rock grooved lengthwise of the valley, i. e., nearly parallel with the flow of the local glacier, which it is well known lingered here for a time after the great ice-sheet had melted. These were not the ordinary glacial scratches, but had the gouged appearance and conchoidal depressions made by sand-laden water. Some of these places were above the highest level of the river during the Champlain floods. A fair inference is that the unusual grooves were probably due to the muddy sub-glacial streams of the local glacier. But even if we admit sand-carving of the underlying rock by sub-glacial streams, can we do it in the case of moraine stuff held in the ice? I have failed to find any recorded observation on this point, though the Alpine glaciers ought to afford facilities for such observations. If

at Bethel bowlderets and smaller stones were held so long in one position in the ice as to be sand-carved, then, either such sculptured surfaces ought to be common in the kames, or we must re-cast our theories as to the kames being deposited by glacial streams. During an investigation of several years, the writer has failed to find a well marked instance of pure sand-sculpturing in the kames and osars, though now and then there are indistinct traces of it.

During the past summer the writer, in the course of an investigation of the glacial gravels of the region, has explored the Androscoggin valley from Brunswick to the N. H. line. Incidentally the Bethel mystery was solved. In numerous places, both in Bethel and elsewhere near the mountains, I found bowlders and even small stones which are now being sand-carved *by the wind* as plainly and incontestably as in Colorado. The drifting dunes of fine sand do not produce this effect to any great extent, probably because the stones are covered and uncovered too rapidly. But there are bare spots not protected by grass where coarse sand and gravel are driven back and forth by the wind, and here the carved bowlders can be seen in considerable numbers and in all stages of the process. In some cases it appeared probable that these bare places were where drifting sand had swept over the surface and the till had been partially denuded by the wind in the manner before described. It now became evident why one face of the Bethel bowlders is in most cases unpolished. That rough face was the under surface, and was protected from the attrition. If a bowlder, after having its exposed faces polished, was rolled over by the up-turning of a tree or by any other cause, the other face or faces became polished also. Where a bowlder lay deep in the ground only a small part at the top could be polished. If it lay on the surface evidently every face except the bottom could be carved simultaneously, provided it was not too large. Large bowlders are only carved laterally; their tops, being above most of the flying sand and gravel, weather faster than the progress of the attrition. The freshness of surface noted by Dr. True is due to the fact that the process is recent. Indeed every feature of the Bethel bowlders under consideration is fully accounted for by the hypothesis of sand-sculpturing under the action of the wind. An accessible locality for observing the process of sand-carving now in operation is found about one mile from West Bethel on the east side of the road leading to Mason. The fields around Bethel village have so generally been plowed that one finds it hard to determine their original condition.

U. S. Geological Survey, October, 1885.

ART. XIV.—*The Westward Extension of Rocks of Lower Helderberg Age in New York;* by S. G. WILLIAMS.

IN a paper published in this Journal, September, 1885, it was shown that the extensive plaster beds of Cayuga County, near Union Springs, are associated with limestones both above and below them, containing fossils of the Water-lime Group and of some of the lower stages of the Lower Helderberg, like *Eurypterus remipes*, *Leperditia alta*, *Nucleospira ventricosa*, *Meristella bisulcata* and *Spirifera Vanuxemi*, and hence it was inferred that their geological position is as high as the summit of the Water-lime Group, rather than in the Salina, as they have heretofore been thought to be.

I wish now to return to the subject to show that the Lower Helderberg period, including all above the Water-lime Group, is represented at least as far west as Cayuga Lake, by limestones not less than sixty-five feet in thickness, containing an unmistakable Lower Helderberg fauna; as well as to compare with this series of rocks the results of some examination of strata of similar geological position on the outlet of Skaneateles Lake and at Oriskany Falls.

The rock series in Cayuga County which is interposed between the gypsum beds and the Oriskany sandstone consists of from sixty-five to seventy feet of impure limestones, partly of a drab color, and partly blue which mostly weather drab. Fossils are quite rare in these rocks, and from this fact, coupled with their usual drab color on weathering, and their proximity to the plaster beds which were assigned to the Salina period, they have hitherto been thought to belong to the Water-lime Group, while the Lower Helderberg proper has been thought to be unrepresented west of Oneida County. Thus Vanuxem, p. 123 of his Report on the 3d District of New York, says that the immediate associates of the Oriskany sandstone cease before reaching Cayuga Lake, and that the Oriskany rests on the Manlius Water-lime; and Professor Hall says, Paleontology of New York, vol. iii, p. 37, that the Lower Helderberg, from which he excludes the Water-lime, making the Tentaculite its base, is scarcely known west of Oneida County. In the final reports of the 3d and 4th districts, however, the Tentaculite limestone is included in the Water-lime Group, the fossils which are figured as belonging to it are chiefly those which characterize the Tentaculite limestone, and several of these are mentioned by Prof. Hall as occurring at a single locality in Ontario County.

Now rare as fossils are in the strata under consideration in Cayuga County, careful search has brought to light a number

of moderately fossiliferous localities in which have already been found at least fifteen species of fossils, two or three of which are probably undescribed, though showing apparent Lower Helderberg affinities, while the remainder all belong to the lower members of the Lower Helderberg, and not one has yet been found which is distinctive of the Water-lime. *Leperditia alta*, which occurs somewhat frequently in the beds below the gypsum in close proximity to *Eurypterus*, has not yet been found above. *Spirifera Vanuxemi*, which with *Leperditia alta* is so abundant in the Tentaculite limestone of Schoharie County, and which occurs in like association in the Lower Helderberg rocks at Put-in-Bay, Ohio, has been found well-preserved about eight feet above the gypsum, at the only point where it has been laid open with a roof of rocks; and traces of it have also been found at some other stations, one of which, though a somewhat doubtful occurrence, is only about ten feet below the Oriskany sandstone. *Strophodonta varistriata* and *Rhynchonella semiplicata* are tolerably abundant at two or three localities; *Strophodonta planulata?* occurs in a blue stratum not far below the Oriskany, associated with an aviculoid shell probably *Megambonia aviculoidea;* and the lamellibranch which is described as *Anatina? sinuata* in vol. iii of New York Palæontology, is found more abundantly and better preserved in a bluish limestone near the base of the series than as yet it has been discovered elsewhere. The most abundant fossil is *Stromatopora*, which is found near the base of the series and at its very summit, and at two localities a half mile distant from each other forms a large part of a stratum nearly four feet thick. With it is associated occasionally *Favosites Helderbergiæ* and a species of Zaphrentis. Besides these fossils, *Nucleospira ventricosa* and *Meristella lævis* occur very sparingly, the former having been found at a single locality, and a small form of the latter at two; and there are also, besides undeterminable impressions of a medium-sized Rhynchonella, a Lingula, a large Platyceras, and a branching fucoid which seems to be undescribed, as also a curious fragment which may possibly prove to be a longitudinally fluted Orthoceras. Sparing as are the fossils of these rocks, it may easily be seen that they are all Lower Helderberg forms which prevail chiefly in the Tentaculite and Lower Pentamerus divisions, with a few somewhat doubtful forms of the Delthyris Shaly Lime. Professor James Hall, who recently made a brief examination of this series of fossils, recognized their character as distinctively Lower Helderberg. There are however no indications of the subdivisions which make so striking a figure in the eastern part of the State; nor could these be expected amid such general uniformity of lithological character as here prevails. It is of interest never-

theless, to learn that the circumstances which favored the deposition of a series of limestones of diverse physical characters with a rich and varied fauna in Eastern New York during the Lower Helderberg period, were not wholly interrupted farther westward, as has been supposed, at the close of the Water-lime epoch; but continued in a modified form and under simpler and more uniform conditions possibly to its very close, marked by the prevalence only of a few of the hardier and more persistent forms of life.

The limestones which underlie the Oriskany sandstone on the outlet of Skaneateles Lake, about fifteen miles east of the region just described show an exposure so far as they are laid open by quarries, of thirty-five feet, but Mr. E. B. Knapp, a careful local geologist, judges their entire thickness to be more than double this. Any attempts at inferring the thickness of these beds without actual measurement is, however, liable to errors, since the local disturbances which were noted in my paper on the age of the gypsum deposits as affecting the corresponding strata on Cayuga Lake, occur here also, the extensive quarries revealing a synclinal bend of a few degrees dip, and with an east and west strike. The beds which admit of definite measurement consist, in ascending order, of nine feet of bluish limestone well supplied with *Strophodonta varistriata* and *Spirifera Vanuxemi;* from ten to eleven feet of dark drab beds in three seams which are largely burned for hydraulic lime; three feet and a half of blue limestone which is highly esteemed for quicklime; and twelve feet of blue limestone of highly variable and often siliceous character. Immediately beneath the Oriskany sandstone the upper member of the series is replete with *Stromatopora* and *Leperdita alta*, and contains besides, *Spirorbis laxus*, somewhat abundant and beautifully preserved *Holopea* (*Littorina*) *antiqua*, and occasional *Favosites Helderbergiæ*. I have observed also with these a single example of *Spirifera Vanuxemi*, although Mr. Knapp assures me that it rarely occurs above the Hydraulic lime. The small series of fossils here enumerated, as well those prevailing below the hydraulic beds as those which are found above, certainly indicates the horizon of the Tentaculite Limestone as it occurs in the eastern part of the State; and the similarity to that group is strengthened by the occurrence at its summit of a bed of Stromatopora, recalling the "thin mass of limestone consisting almost entirely of the coral Stromatopora, and constituting a very persistent member of the group," which Professor Hall gives, p. 37, vol iii, of New York Paleontology, as the uppermost member of this limestone in the east. Whether however this fact indicates that strata synchronous with the higher members of the Lower Helderberg series were never deposited in this region, where the limestones are suc-

ceeded regularly by the Oriskany sandstone without any visible indications of an intervening land condition; or whether it may be interpreted as due to the persistence of species which alone were adapted to the conditions of existence here presented, is a question to which it is not easy to give a definite answer. The fact that several species indicating higher horizons are intermingled with some of these on Cayuga Lake, and that two of the Skaneateles species occur with a few others in apparently correspondent strata still farther westward in Ontario County (Report on 4th District, p. 141) may possibly give some support to the latter hypothesis; as may also the occurrence of *S. Vanuxemi* and *Tentaculites gyracanthus* high up in the thick Lower Helderberg series of Pennsylvania. (Report, F^2, pp. 61 and 182.)

The exposure of Lower Helderberg rocks at Oriskany Falls, eighteen miles south of Utica, is interesting, partly because it is so laid open by deep and extensive quarries as to give nearly a complete section of about 120 feet of rocks, 115 feet of which can be definitely measured from the Oriskany sandstone, here ten feet thick, down to the bank of the abandoned Chenango canal; and partly because, while highly fossiliferous at several levels, it shows the condition and tendencies of the Lower Helderberg limestones at a point nearly midway between Schoharie County and Cayuga Lake. The uppermost twenty-five feet of limestones at this locality which are largely covered by soil, where they are revealed at top and bottom, are shown to be a gray, sub-crystalline rock which, where it can be reached immediately beneath the Oriskany, is replete with *Merista arcuata* and an occasional *Strophodonta radiata*. At the base of this series of gray beds is a remarkable seam, about a foot thick, filled with *Pentamerus galeatus* and *P. Verneuilli*, *Rhynchonella mutabilis* and *R. altiplicata*, *Atrypa reticularis*, *Orthis concinna*, *Strophodonta varistriata*, *S. punctulifera* and *S. planulata*, and occasionally *Spirifera Saffordi* and several other species, the same fossils being also somewhat abundant in the three to four feet above this seam which are opened by the quarries. Indeed the difficulty in establishing any divisions like those farther eastward, is not, as Professor Vanuxem found it here forty-five years ago, from a scarcity of fossils, but from the complete intermingling of Lower Pentamerus and Shaly Lime species, both in these beds and in the limestones for fully forty feet below them. Just beneath the Oriskany indeed, at the single point where it could be conveniently reached, I found only the two Shaly Lime species that have been named; but it is quite possible that this is merely a casual occurrence, and that were these beds as thoroughly opened as those below, the same intermingling of species would be found to hold good.

These gray beds are also, as Vanuxem remarked, dissimilar in physical character to the Shaly Lime of Schoharie County, and, though gray and somewhat crystalline, bear no great resemblance to the rough Pentamerus limestones of the eastern localities.

Below these gray beds, the limestones for about ninety feet are of a prevailing blue color, and, with an exception presently to be mentioned, are so pure as to be very largely quarried for lime-burning and for a flux in the iron furnaces a few miles north near Clinton. For twenty-nine feet below the gray beds, these blue limestones show but few fossils save *Favosites Helderbergiæ* and *Stromatopora* which are tolerably abundant. Below these occur about seven feet of impure, slightly magnesian, grayish beds, often highly laminated and occasionally presenting beautiful ripple-marks, testifying to a considerable temporary change in the conditions of deposition. The impurities in these beds, amounting to 20 per cent of insoluble matter chiefly siliceous, render them unfit for lime-burning, and they are used for building stone. Though not remarkably rich in fossils, many of the slabs show fine large *pygidia* of *Dalmania pleuroptyx* and occasional *Discina discus*, and I observed one large slab which, besides several individuals each of these two species, had also a beautiful *Conularia* unlike those described in vol. iii, Paleontology of New York. *Dalmania pleuroptyx* continues for several feet below the building stone beds, from which point downward for about forty-five feet few fossils are seen save *Stromatopora*, *Favosites Helderbergiæ*, *Strophodonta varistriata*, and rarely *Spirifera Vanuxemi*. *Euomphalus sinuatus* has also been given me as from these beds. Near the base of the 115 feet of strata which I measured, *Stromatopora* is found very abundantly associated with *S. varistriata* in thin-bedded limestones. In beds a little below my measured section, reached by going northward along the banks of the abandoned canal, since its waters flow northward while the strata all dip gently south, *Spirifera Vanuxemi* and *Leperditia alta* are found in great abundance with a few *Spirorbis laxus* and *Chætetes fructicosus*, while an occasional thin layer abounds in the Tentaculite which occurs in such myriads at a like horizon in the eastern localities.

The lower strata of the series for nearly fifty feet contain, therefore, apparently only fossils which are found commonly in the Tentaculite limestone, and they doubtless correspond well with that stage. Possibly also the very uppermost beds, unlike as they are in physical character to the Shaly Limestone of the eastern counties, may be parallel with that horizon; but from the complete intermingling of forms characterizing the Lower Pentamerus and the Shaly Limestone in fully fifty feet

of strata, including at least a portion of the gray beds, it does not seem possible to separate these groups definitely, while nothing answering to the Upper Pentamerus occurs here.

This description of the Lower Helderberg at Oriskany Falls has been given to call attention to the fact that a series which in Schoharie and Albany Counties presents four strongly marked changes in rock characters, accompanied by considerable differences in the grouping of specific forms, has here, with some apparent diminution of total thickness, become of much more uniform lithological character, even the gray limestones which crown the series lacking that massive and rough-weathering appearance which is so prominent at the east; and that this simplification of rock characters is accompanied by a tendency to obliteration of any definite divisions characterized by distinctive groups of fossils, the Tentaculite limestone horizon only being here clearly marked, and showing a tendency to retain its dominant life characters after the individuality of the other divisions has been lost by the blending of their faunas. In the Skaneateles section, as has already been seen, the life of the Tentaculite Lime only is represented, with the exception of *Favosites Helderbergiæ*, and the beds worked for hydraulic lime occur near the summit of the series; while on Cayuga Lake the seventy feet of limestones to which the Lower Helderberg, exclusive of the Water-lime, is there reduced, have all subdivisions quite obliterated, contain Stromatopora at two different levels and probably at three, and, while retaining two or three common fossils of the Tentaculite, vindicate their right to represent a large portion if not the whole of the Lower Helderberg period by containing a considerable number of its characteristic forms, including *Platyceras*, unmixed with any Water-lime species, as well as by lying above strata holding *Eurypterus* and *Leperditia alta*.

It may be remarked that the three sections that have here been given, as well as the widely-known series in Schoharie County with which they have been compared, all have well-developed Oriskany sandstone to mark their upper limit, showing the probability that all are equally complete as they were deposited, and if so, that all are probably synchronous since they are all equally free from any indications of having been withdrawn from deposition by becoming land areas. If this be true, their differences both of lithology and life must be due to differences in circumstances of deposition in different portions of the same long Silurian coast-line. Indeed, when it is considered that the Onondaga Salt series, which is very thick in Ontario and in Western and Central New York, thins out entirely in the east; that the non-saliferous representative of the Onondaga (Salina) in Pennsylvania has, in a portion of its

extent, many interstratifications of limestones in the upper two-thirds of its thickness, and where thickest in Perry County, contains the Lower Helderberg forms, *Leperditia alta* and *Beyrichia notata*, low down in the series, while according to Prof. Claypole it is not definitely separable from the Lower Helderberg above (Pennsylvania Reports, F^2, G^6 and G^7); and that the Lower Helderberg which is very thin in Ohio, Ontario and western New York, thickens eastward, shows its distinctive life characters on Cayuga Lake, and attains its fullest and most diversified development in eastern New York, where the saliferous series has quite died out. It seems not impossible that these two formations, usually considered distinct, may have been to a large extent simultaneously deposited, the one in lengthened basins near the sea border, which when filled with their peculiar accumulations, gave place to sea-shore deposits of limestones, often impure, as in the west; the other, in open waters which, at first contaminated with mechanical sediments, later became clear, and in which, from oscillations of level affecting chiefly its eastern areas, limestones of varied characters were accumulated whose western extension had little variability. Under such circumstances, it would not be difficult to conceive why the Lower Helderberg should thin to the westward where the Salina appears in greatest volume, nor why it should there be represented by impure limestones, resembling the lowest portion of the eastern series, while more nearly synchronous with its higher portions. It would also be natural to expect, in this case, that the fauna of the western strata would consist of forms migrating from the east, and, on this account, partaking largely of the life characters of the lower eastern deposits, since such migrations are likely to take place very slowly.

Art. XV.—*Meteoric Iron from Jenny's Creek, Wayne County, West Virginia;* by George F. Kunz.

[Read at New York Academy of Sciences, Nov. 30, 1885.]

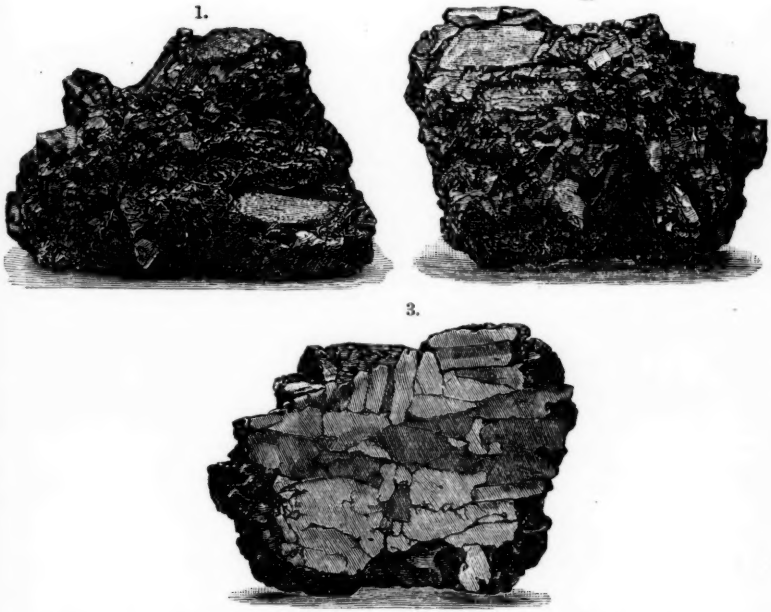
During the early part of last April a 9-ounce piece of mineral, supposed to be silver, was sent to Dr. H. G. Torrey for determination, by Major Delafield Du Bois, of Charleston, West Virginia. Dr. Torrey found it on examination to be an iron of meteoric origin, and kindly loaned it to me for description. The piece delivered to me was supposed to be all of the fall, and on this supposition it was described as the Charleston, Kanawa County, West Va., meteorite, in a paper read at the Ann Arbor meeting of the American Association. Through the

kindness of Major Du Bois, Mr. J. F. Hoard and Dr. John N. Tilden, who went to considerable trouble in ascertaining it, I am able to announce the true locality.

Mr. Hoard writes that the iron was found on land belonging to Maston Christian, situated on the "Old Fork" of Jenny's Creek, a tributary of the "Tug Fork" of Big Sandy River (Tug Fork being the boundary line between West Virginia and Kentucky), in the upper end of Wayne County. The pieces were all found in the creek bed, i. e. the ravine or gulch through which the creek flows. The first piece, weighing probably two or three pounds, was found by Christian's wife sometime earlier than the spring of 1883. It was supposed to be simply a rich "kidney" of limonite, and was soon lost sight of. In the spring of 1883, however, a second piece was found by Christian himself while drifting staves in the creek. This piece, which weighed about twenty-three pounds, created considerable excitement and speculation. It is even stated that a shrewd speculator, who had in his possession a lump of the metal, had realized largely by burying it on different lands, digging it up again, and then selling the pieces of property successively as being silver-bearing. The rumor was current that the vein was from nine to sixteen inches thick. It was broken up and distributed among several parties interested in the find, and as it was friable, much of it was lost in this manner. About the first of December, 1885, a third fragment was picked up by Mr. Christian in a pool of still water, only about fifteen or twenty feet from where he had found the other. It weighs 535 grams (about seventeen ounces), is all broken except one side which is altered to limonite and has no visible trace of unaltered crust. Its measurements are 88^{mm}, 57^{mm}, and 46^{mm}. The total amount found thus far in the three pieces is probably twenty-six or twenty-seven pounds. Both of these latter pieces were found in water and had a coating of rust or earthy matter similar to that found on "kidneys" of ore, which was removed easily with the hands or by washing.

The iron is octahedral and made up of crystalline blocks of plessite and kamacite, irregular in shape, brittle, having rounded ends and cleaving readily. Between these are also thin, springy and flexible folia or plates of schreibersite, some of which are 6 or 8^{mm} square. The latter mineral was also observed in two other small pieces sent to me. Troilite was also observed in these. The original weight of the piece loaned me for description was 275 grams; one small slice of 34·5 grams weight had been removed to show the internal structure, so that the larger piece, fig. 3, now weighs 228·2 grams. The three cuts show the exact size of these pieces, and the markings on the etched surface as well as the octahedral structure

on the exterior of the iron have been accurately reproduced by photography direct from the iron. (Original size as follows: length, 66mm; width, 40·5mm; height, 33·5mm.) The exact date of the fall of this iron is not known, and the surface



where not cracked off is altered to limonite to a depth of 2mm. It belongs to the "grobe Lamellen" of the new classification of Dr. A. Brezina. The Sevier County, Tenn., and the Arva irons nearest approach it in structure. The following analysis was kindly made by Mr. J. B. Mackintosh, E.M., of the School of Mines, New York:—

Iron	91·56
Phosphorus	0·13
Nickel and cobalt (by difference)	8·31
	100·00

The specific gravity of the figured mass is 7·344. The iron does not show any Widmannstätten figures, the crystalline structure being really brought out in relief by the schreibersite between the crystalline surfaces of the iron.

Since this iron was broken and scattered in small pieces, we may expect to see them turn up as a number of different falls.

but the coarsely crystalline structure, and the broken appearance of the pieces which are characteristic of this fall, will at once identify them.

The late Judge M. J. Ferguson, while residing at Louisa, Ky., communicated to Mr. S. Floyd Hoard, that one summer about five years ago, at about 1 A. M., he witnessed a meteor of wonderful brilliancy falling in the direction of the spot where these fragments have since been found; and that he predicted at the time that one would probably be found in that vicinity. The windows facing that way were open, and the curtains drawn back. The light was as brilliant as noonday, and of sufficient duration for him to step to the window and see the meteorite fall, as he thought a short distance away, and surely within the limits of Wayne County.

There is, therefore, a strong probablity that the pieces now being described are fragments of the identical meteorite which startled Judge Ferguson on that night. The fact that these masses of meteoric iron were found in water, and that all the branches of the creeks in this county are subject to strong floods of a few hours' duration, but while they last, sufficient to float logs, may account for the finding of these three pieces (evidently fragments of one piece of very friable iron), scattered as they were, and also for the oxidation of the crust of the iron, which might have remained intact for a much longer period, had the meteorite buried itself in the earth. Of the twenty-six or twenty-seven pounds which were found, only about two pounds have been preserved. I am under obligations to Major Delafield Du Bois, S. Floyd Hoard, and Dr. John N. Tilden, for obtaining information and material.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Separation of Liquefied Atmospheric Air into two layers.*—In his first paper on the liquefaction of air, Wroblewski noted the fact that the phenomena observed were not those of a simple gas, but resembled more nearly those of a mixture, the components of which had different laws of liquefaction. The critical point so-called, of air for example, arises only from the fact that the tension-curves for oxygen and nitrogen agree so closely; the pressure lying between 37 and 41·3 atmospheres, and the temperature between $-140°{\cdot}8$ and $-143°$. In the present paper the author shows that when air is liquefied under high pressures and then exposed to a pressure of only one atmosphere, the boiling point rises gradually from $-191{\cdot}4°$ to $-187°$, owing to a

change in the composition of the liquid, the nitrogen evaporating more rapidly than the oxygen and the boiling point approaching that of oxygen, −181·5°. When evaporated in oxygen, the tension steadily diminishes and the temperature passes through a series of maxima and minima. But more than this. The liquefied air may separate into two distinct layers differing in appearance and in composition and defined by a sharp meniscus. To obtain this separation, a certain quantity of air is liquefied at −142°, and gaseous air allowed to enter into the tube until the pressure is 40 c. m. and its optical density is equal to that of the liquid, the meniscus entirely disappearing. The pressure is then slowly reduced, and when it reaches 37·6 atmospheres, a new meniscus forms at a point in the tube much higher than the place previously occupied by the vanished meniscus. Presently the former meniscus reappears in its old position and two liquids are distinctly seen superposed. In some seconds bubbles form at the lower meniscus, rendering the upper liquid opaque and ultimately destroying the dividing meniscus and leaving a homogeneous liquid. By the introduction of a small metal pipette the author has removed portions both of the upper and of the lower layer and has analyzed them. The lower liquid contained 21·28 to 21·5 of oxygen, the upper one 17·3 to 18·7. This experiment clearly shows that the disappearance of the meniscus of a liquid when it is obtained by increasing the pressure exerted by a gas on a superposed liquid, does not effect a solution of the liquid in the gas.—*C. R.*, ci, 655, Sept. 1885; *Phil. Mag.*, V, xx, 463, Nov. 1885. G. F. B.

2. *On the Velocity of the Explosive wave in Liquid and Solid Detonants.*—BERTHELOT has supplemented his researches on the velocity of propagation of the wave of exploding gases, by a similar series of investigations on the velocity of the explosive wave in detonating solids and liquids. For this purpose the explosive was placed in a tube of block tin or lead, or an alloy of the two, one to two millimeters in interior diameter and of varying length up to 100 or 200 meters. It was distributed as uniformly as possible, and in some cases compressed in the tube. The explosives used were gun cotton, both in the ordinary form and granulated, nitro-starch, nitro-mannite, dynamite, nitroglycerin and panclastite. Most of the measurements were made on Sébert's velocimeter, though a fall-chronograph and a Le Boulengé chronograph were also used. At the ends and at 25 meter intervals, the tube containing the explosive was surrounded by fine conducting wires leading to the registering electro-magnets. These wires being successively ruptured by the explosion, the order of the phenomenon was registered on a smoked surface, simultaneously with the vibrations of a tuning fork of known rate. A single experiment, made on the 27 Sept., 1882, will show the method of operating. Tubes 6 mm. interior and 10 mm. exterior diameter, were filled with nitroglycerin. The progress of the wave of explosion was registered on a Le Boulengé chronograph by the breaking of the copper wires attached to the tube. The explosion was effected by

means of 1·5 grams fulminate in one end of the tube. In the first trial the tube used was 14·46 meters long between the interrupters, the first of these being placed 4 cm. behind the detonator, and the second 4 cm. from the other end. The time required for the wave to travel through the tube was 0·013980 second; which gives 1034·4 meters as the velocity of the explosive wave. In a second trial, in which the tube was 11·77 meters long, the time was 0·011491 second; giving a velocity of 1024·3 meters. The results show that the velocity is affected by the compactness of the charge, the size of the tube and even by the material of which it is made. With ordinary gun-cotton for example, experiments made in 1884 show that in lead tubes 4 mm. external diameter, the density of the charge being from 1 to 1·2, the mean velocity for lengths of 100 meters varied from 4952 to 5500 meters per second, and for successive intervals of 25 meters, from 4671 to 5980 meters per second. In tubes of tin, the density of charge being 1·2, the velocity was from 5736 to 6136 meters per second in tubes 4 mm. external diameter, and 5845 to 6672 meters for those of 5·5 mm. diameter. For gun cotton from hydrocellulose, the mean velocity in tin tubes of 4 mm. diameter was 5916 meters, and in those of 5·5 mm. 6100 meters; the velocity in lead tubes 4 mm. diameter being 5200 meters. With granulated gun cotton densely charged, 1·17, in a 4 mm. tube, a velocity of 4770 meters was obtained. In lead tubes 5·5 mm. external diameter, the density of the charge being 1·27, the mean velocity was 5406 meters. With a less density of charge, 0·67 to 0·73, in lead tubes 8·44 to 10·6 mm. external diameter, the mean velocity varied from 3767 to 3795 meters. With nitro-starch, in a tin tube 4 mm. diameter, the density being 1·2, the velocity varied from 5222 to 5674 meters, and in a tube 5·5 mm. 5816 meters. In a lead tube of 4 mm. the density being from 1·1 to 1·2, the velocity varied from 4886 to 5006 meters; rising to 5512 when the density was increased to 1·35. Nitromannite with a density of 1·5 gave a velocity of 6965 meters; with a density of 1·9, of 7705. Nitroglycerin could not be made to detonate in lead tubes smaller than 3 mm. internal diameter, unless the temperature was above 14°. Tubes of this size placed in the sun gave velocities of 1310, 1015 and 1286 meters. Dynamite in Britannia tubes 3 mm. internal diameter, gave a velocity of 2333 to 2753 meters. In lead or Britannia tubes 6 mm. interior diameter from 1916 to 3180 meters; the mean of all being 2668 meters. Panclastite (equal volumes of petroleum of gravity 0·710 and hyponitric acid) in a tube of tin 5 mm. in diameter and 25 meters long, gave unsatisfactory results. By using equal volumes carbon disulphide and hyponitric acid, in a lead tube 3 mm. in diameter, a velocity of 4685 meters was obtained in one experiment and 6658 meters in another.—*Ann. Chim. Phys.*, VI, vi, 556, Dec. 1885. G. F. B.

3. *On the Visible representation of the Ultra-red Rays.*—In the well known experiments of Tyndall on Calorescence, the focus of the ultra-red rays, obtained by means of an absorption cell filled

with a solution of iodine in carbon disulphide, is made evident by the incandescence of a platinum plate. LOMMEL suggests the use of phosphorescent substances to render this focus visible. Balmain's luminous paint answers the purpose; but the author prefers a greenish-blue phosphorescent calcium sulphide. When this has been made slightly phosphorescent by ordinary daylight, it is increased to a bright luminosity by the less refrangible, especially the ultra-red, rays. When the radiation is moderately strong, this luminosity lasts for hours and is visible for some time even after the radiation ceases. Then a dark spot takes the place of the bright one, the luminous power having been diminished or entirely destroyed in consequence of the increased emission. If the powder be placed between two plates of glass, the ultra-red portion of the spectrum produces a greenish-blue phosphorescence visible on both sides of the glass. If the dark focus be received on this screen, it appears as a bright spot on a feebly luminous ground, which changes into a black spot after some time, looking as if a hole had been made through the luminous surface. The author suggests the use of a solution of nigrosin in chloroform or alcohol in place of the iodine in carbon disulphide employed by Tyndall, for filtering out the luminous rays. The nigrosin transmits only ultra-red rays. Since these rays are considerably absorbed by alcohol the solution in this menstruum answers well for the above described experiment, since the phosphorescent luminosity lasts longer. The solution in chloroform is much more diathermanous and answers well for showing the thermal effects at the focus. So sensitive are these phosphorescent substances to the ultra-red rays, that the flame of gas, of a lamp or even of a candle may be made to show the phenomenon. Using a lens and a cell filled with the black liquid, a sharp bright image appears on the screen, which gradually diminishes and finally changes into a dark image on a brighter ground.—*Wied. Ann.*, II, xxvi, 157, 1885; *Phil. Mag.*, V, xx, 547, Dec. 1885. G. F. B.

4. *Improved method of preparing Nitrogen dioxide.*—KAEMMERER has suggested an improved method of preparing nitrogen dioxide by which a much steadier flow of this gas is secured. The apparatus consists of a two-necked Woulfe's bottle, having a dropping funnel in one of the openings and an evolution tube suitable for washing or drying the gas in the other. The bottle is one-third filled with a saturated solution of sodium nitrate, and strips of copper are introduced. To evolve the gas, concentrated sulphuric acid is allowed to flow into the bottle more or less rapidly according to the quantity of gas desired. With a bottle of two liters capacity and a funnel-tube of 500 c. c., the yield of nitrogen dioxide gas may be maintained steady at the rate of a liter in five minutes.—*Ber. Berl. Chem. Ges.*, xviii, 3064, Dec. 1885. G. F. B.

5. *On the Action of Carbon monoxide and the vapor of Water at high Temperatures.*—NAUMANN and PISTOR have continued their researches on the phenomena attending the produc-

tion of water gas and have now studied the reaction which takes place at high temperatures between the vapor of water and carbon monoxide. The gases were passed through a glass tube containing a layer of pumice-fragments 80 cm. long. The carbon monoxide prepared from potassium ferrocyanide and sulphuric acid and purified from oxygen and carbon dioxide by phosphorus and potassium hydrate, passed through water heated to 80° on its way to the tube; thus giving a mixture of about equal molecules. The tube was heated in a combustion furnace, the temperature being determined by means of the melting of salts of known fusing points. In the first experiment, in which the temperature lay between the fusing point of silver iodide (530°) and pyrophosphate (585°) the evolved gas contained no carbon dioxide and after explosion with oxygen no indication of the presence of hydrogen; a result confirmed by a second experiment. In the third experiment, the temperature was carried to between 602° and 634°, and the evolved gas contained 1·5 per cent carbon dioxide and 3 per cent hydrogen. For higher temperatures, porcelain tubes were used 8 mm. diameter, heated in a Fletcher furnace. The carbon monoxide, carefully freed from the dioxide and oxygen was mixed with water vapor and in the fourth experiment passed into the tube, heated in the furnace to between 861° and 854°. On analyzing the issuing gas, 8 per cent of carbon dioxide was found present. In the fifth experiment, the tube was filled with pumice for a length of 25 cm. The gas evolved contained 10·6 per cent carbon dioxide. Since the silver spiral placed in the tube had melted and the copper spiral had not, the temperature reached must have been 954°. Hence it appears that no apparent reaction takes place between carbon monoxide and water vapor at 560°; that at 600° about 2 per cent, at 900° 8 per cent, and at 954° about 10·5 per cent of the monoxide is converted into dioxide. Thus the very conditions which oppose the action of hydrogen upon carbon dioxide, favor the action of water vapor upon carbon monoxide.—*Ber. Berl. Chem. Ges.*, xviii, 2894, Nov. 1885. G. F. B.

6. *On the Atomic weight of Cerium.*—BRAUNER has made an elaborate investigation of the cerium group of metals and now gives the results of his determinations of the atomic weight of cerium. For this purpose anhydrous cerous sulphate was employed, the atomic weight being calculated from the ceric oxide which this salt left on ignition. For the preparation of the sulphate, the crude oxides obtained from cerite were dissolved in nitric acid, the excess of acid removed by evaporation, the syrupy liquid slightly diluted and poured into a large quantity of pure boiling water. Almost the whole of the cerium present was precipitated as basic ceric nitrate. After washing this was dissolved in nitric acid and again precipitated with water; thus obtaining a series of fractions. To obtain the cerous sulphate, the ceric nitrate was dissolved in sulphuric mixed with sulphurous acid; the excess of acid evaporated, the heavy metals precipitated with

hydrogen sulphide, and finally a crystalline salt of the formula $Ce_2(SO_4)_3(H_2O)_8$ was thrown down by adding three times the volume of alcohol. A second precipitation gave perfectly neutral cerous sulphate. For final purification, the salt was dissolved in cold water, and the beaker containing it was plunged into boiling water. On stirring it a fine crystalline powder $Ce_2(SO_4)_3(H_2O)_6$ was thrown down which was collected for use. To dehydrate it, it was heated in the vapor of boiling sulphur; since at this temperature it loses its water entirely, but is not otherwise altered. For the analysis a weighed portion of the anhydrous cerous sulphate was placed in a double crucible and exposed for ten or fifteen minutes to the flame of gas fed with air by a Fletcher's injector. It was then cooled and weighed. The greatest care was taken in all the experimental work, of preparation as well as analysis; and is detailed in the memoir. The result of twenty-three determinations is given, the maximum atomic weight being 140·433 and the minimum 140·033, the mean value being 140·2210; thus harmonizing the periodic values of the group.—*J. Chem. Soc.*, xlvii, 879, Nov. 1885. G. F. B.

7. *On the Synthesis of Cocaine and its Homologues.*—By treating anhydrous ecgonin with benzoic oxide and methyl iodide for ten hours to 100° in a sealed tube, MERCK has produced cocaine. Substituting ethyl iodide, the same reaction gave him its ethyl-homologue, which crystallizes from alcohol in brilliant prisms fusing at 108°–109°. Platinum chloride produces even in very dilute solutions of its salts a yellow precipitate soluble in hot water and crystallizing on cooling in brilliant yellow rhombic plates. Ladenburg proposes for it the name cocethyline.—*Ber. Berl. Chem. Ges.*, xviii, 2952, Nov. 1885. G. F. B.

8. *Electrostatic Battery.*—Mr. Damien having conducted investigations during a period of ten months upon single liquid batteries of various kinds, concludes that a cell formed of zinc and copper with the sulphate of magnesia is the best for electrostatic measurements. Instead of increasing the resistance of the cell by mixing the sulphate with plaster of Paris as in the Beetz cell, he puts in an outside resistance. With a resistance of 20,000 ohms in the circuit the cell remained constant even when short circuited. He finds that the electromotive force of this cell is very nearly constant, and is not sensibly affected by slight changes of temperature or by the concentration of the solution.—*Ann. de Chim. et de Phys.*, 16e série, t. vi, Nov. 1885. A. L. MC R.

9. *Handbook of technical Gas-Analysis;* by CLEMENS WINKLER; translated with a few additions, by GEORGE LUNZE. 125 pp. 8vo. London, 1885, (John Van Voorst).—The contributions of Dr. Winkler to technical gas-analysis have given him a foremost position among the writers upon this subject. This volume, though small in extent contains the practical instructions needed as well by teachers as by technical workers, and ought to be in the hands of all interested in the subject of which it treats. The name of the translator is a sufficient guarantee of the character of his part of the work.

10. *Alternating Currents of Electricity;* by THOMAS H. BLAKESLEY. 90 pp. 8vo. London, 1885.—This volume contains a series of papers, reprinted from the pages of the Electrician, discussing by the geometrical method alternating or harmonic currents of electricity.

II. GEOLOGY AND NATURAL HISTORY.

1. *Dr. Frazer's Report on the International Geological Congress.*—Dr. Frazer's Report published in the last volume of this Journal has had high commendation from the Secretary of the Congress.* In two points there were misunderstandings, and he has sent the following corrections.

(1.) Dr. Newberry corrects the last two words of the 18th line from the bottom of p. 469 in the last volume of this Journal from "no strict" to "a strong," thus making the sentence read . . . "and there is a strong line of demarcation between the Trias and the Permian." But he prefers to omit this line altogether. He sends the enclosed note of his remarks on this subject *in extenso.*

"In the discussion on the Permian, in North America, I said that 'In North America there is no strict line of demarcation between the *Permian* and *Coal-measures*, one shading into the other imperceptibly in stratification and fossils; there is no physical nor vital break, and while new forms come in toward the top of the series, such as *Monotis*, *Pleurophorus*, *Bakevellia*, etc., these are accompanied by some of the characteristic coal-measure species such as *Spirifer cameratus*, *Athyris subtilita*, *Productus semi-reticulatus*, etc. On the other hand, the most characteristic fossils of the Zechstein and Copper schists, plants (*Ullmannia*, *Voltzia*, *Walchia*, etc.), fishes (*Acrolepis*, *Pygopterus*) and mollusks (*Productus horridus*, etc.), have so far not been found in North America.' The Trias of the eastern half of North America represents the upper member of the European series, the Rhætic beds. [This is shown by the plants described by Emmons and Fontaine from North Carolina and Virginia, and those obtained from New Jersey and the Connecticut valley by the writer.†] Hence between our coal measures or the so-called Permo-Carboniferous or Permian and our Trias there is a great gap, a hiatus in our geological history, during which the Permian proper of Europe, at least the Zechstein and Copper schists, were perhaps deposited."

* M. Fontannes, the Secretary, in a letter to Dr. Frazer, dated Lyons, Jan. 3, 1885, says: "Je viens de lire, avec le plus grand soin, le rapport sur le Congrès de Berlin que vous avez eu l'amabilité de m' envoyer. Tous mes remerciments, et en même temps toutes mes félicitations pour l'exactitude rigoureuse de tous les détails. Il m'est impossible de comprendre comment, en l'absence de mes notes et de celles des stenographes, vous avez per rédiger un travail aussi complet." * * *

† H. B. Geinitz: *Dyas* (1861–2). H. B. Geinitz: *Carbonformation in Nebraska*, (1866). H. B. Geinitz: *Nachträge zur Dyas*, 1880–2). Wm. Fontaine: Older Mesozoic Floras of Virginia; Monograph VI., U. S., Geol. Survey. J. S. Newberry: Transactions N. Y. Academy of Sciences, vol. v, p. 18 (October, 1885.)

(2.) Prof. de Lapparent, of Paris, answers a query as to an apparent contradiction between his theory and his argument: "It is true that the words, (page 468), make me say the contrary of what I said. I have maintained that the *same eruptions* which took place during the Carboniferous epoch were maintained during the Permian epoch, of which the porphyries and melaphyres were the incontestable continuation of the porphyritic and trappean rocks of the Carboniferous; that in consequence, the Permian epoch was the termination of the '*Primary eruptions.*' I will add that (page 467) ascribes to me a not very accurate opinion. I said that the cephalopods of the deposits anterior to the Tertiary terranes furnished an excellent means of forming homogeneous groups; but that this means only commenced to be easily applicable with the Trias. Nevertheless if one considers the *pelagic* Faunas of the Carboniferous and of the Permian, not only do they appear intimately connected, but no one among those who are acquainted with the pelagic Permian will ever be able to establish subdivisions in it. Now, that which distinguishes *the systems* is that they are groups susceptible of being sub-divided. The Permian then, cannot form a system by itself. It cannot but be an *étage* in the great Permo-Carboniferous system."

2. *Cretaceous of Northwestern Canada.* — In a paper by Sir W. Dawson in the Canadian Record of Science, the subdivisions of the northwestern Canadian Cretaceous are given as follows, beginning below. (1) *Lower Cretaceous* (Neocomian, etc.): (*a*) The Kootanie series of the Rocky Mountains containing Cycads, Pines and Ferns; (*b*) the Suskwa River beds and Queen Charlotte Island coal series, containing Cycads, Pines and a few dicotyledons. (2) *Middle* Cretaceous: (*a*) Mill Creek beds of Rocky Mountains containing dicotyledonous leaves similar to those of the U. S. Dakota group; (*b*) Dunvegan series of Peace River with many dicotyledons, Cycads, etc. (3) Upper Cretaceous: (*a*) Coal-measures of Nanaimo, B. C., probably in this position with many dicotyledons, Palms, etc.; (*b*) Belly River beds, the Sequoia and Brasenia beds of S. Saskatchewan, Belly River, etc., with lignites; (*c* and *d*) Fort Pierre and Fox Hill series, marine; (*e*) Lower Laramie or St. Mary R. beds, the Lemna and Pistia beds of Bad Lands of 49th Parallel, Red Deer River, etc., with Lignites. (4) Transition to Eocene: Upper Laramie or Porcupine Hill beds, the Platanus beds of Souris River and Calgary. These results are largely from the investigations of Dr. G. M. Dawson and the author. The latter has a memoir on the subject in process of publication in the Transactions of the Royal Society of Canada.

3. *Journal and Proceedings of the Royal Society of New South Wales for* 1884, vol. xviii.—This volume contains, among its papers, brief notes on the development of Ceratodus and the Monotremes by Mr. W. H. Caldwell. The eggs of the Ceratodus were found in the waters of Burnett River in the early part of September. They were laid singly in the weeds and resembled those of the common newt. They were fertilized in the water and

in this and other respects the development was much like that of the newt. Mr. W. E. Abbott discusses the subject of the water supply of the dry Interior plains of New South Wales. He speaks of this region as really a water shed, and of the amount of precipitation over this great water shed of Darling River as 30 inches a year in the mountains to the eastward and less than 10 inches to the westward. The plains are regarded as having been in comparatively recent geological time "covered by a sea," and as thus having derived its nearly level surface.—On the western side along the railroad it is 349 feet above the sea and 865 feet on the eastern, making the mean slope between about 2 feet a mile. The soil of two-thirds of the surface is a red clay with a slight admixture of fine sand without organisms, and of the rest, a grayish-black earth overlying the red along the water courses. Water is reached at a small depth; but five out of six of all wells sunk afford brackish water and there are many salt springs. The country is called the Salt bush country; the native plants have 30 to 43 per cent of the ash consisting of soda or sodium chloride. Gypsum nodules also are common, pointing, like the salt, to former marine conditions. The author supposes, with Mr. H. C. Russell of the Observatory, that the water of the River Darling becomes largely subterranean water and may be reached by artesian boring. But in view of the cost of such borings he recommends rather the construction of reservoirs for storing the surface water of the streams, and for collecting the water of rains on the slopes.

4. *Fossil Insects of the "Primary" (Paleozoic) rocks*, by CHARLES BRONGNIART. 20 pp. 8vo, with five plates (Bull. Soc. Sci. Nat., Rouen, 1885.—This valuable paper, illustrated by fine heliographic plates, reviews the facts with respect to Paleozoic insects and gives criticisms on the work of other authors. The discovery of the Carboniferous locality of Commentry, which since 1878, has furnished 1300 specimens of insects mostly "admirably preserved," gives great weight to his opinions.

5. *The Determination of Rock-forming Minerals*, by Dr. EUGEN HUSSAK; translated from the German by Dr. ERASTUS G. SMITH. 233 pp. 8vo, with 103 wood-cuts. New York, 1885, (J. Wiley & Sons).—The work by Dr. Hussak on the determination of the minerals which enter into the composition of rocks has been well received abroad, and now that it has been translated it will doubtless be as well known and appreciated among the English-reading public. The work gives, much more fully than has been attempted before in any single volume, the methods employed in the mineralogical study of rocks, optical, chemical and mechanical. A second part consists of tables for the determination of the rock-forming minerals; these give in condensed form a large amount of information about the individual species, which the student of microscopical petrography should make himself familiar with. The translation of such a work is a difficult matter and it is not strange that there are numerous points open to criticism. The reader will probably think that the translator has attempted to follow

the original almost too closely, and that a little more freedom would have sometimes made the rendering smoother and more readily intelligible. It would have been well too if the opportunity had been taken to correct occasional misstatements in the original.

6. *A "Manual of American Land Shells,"* by W. G. BINNEY. Bulletin No. 28 of the U. S. National Museum.—This work is an enlarged and revised edition of the "Land and Fresh-water Shells of North America, Part I," published by the Smithsonian Institution in 1869. Of its 528 pages the author devotes about fifty to the subjects of "geographical distribution, organs of generation, jaw and lingual dentition, and classification, 425 to the description of genera and species, and twenty-eight to a detailed catalogue of the Binney collection of land shells of North America, which Mr. Binney presented to the National Museum. The volume includes only the Geophila among the Pulmonata. The author accepts the division into families in Dr. Paul Fischer's recent work, but follows Alber's "Du Helicum," by Von Martens, in the Genera. The arrangement is not systematic, but according to geographical distribution. It is strange that at this day the author should have to regret the lack of data for determining satisfactorily this distribution. Thirteen species are stated to be universally distributed over the United States. Eleven foreign species occur on the sea-coast. *Limax maximus* is reported only from Newport, R. I., New York city and Philadelphia. We have found it abundantly in gardens in New Haven, Conn. A. G. D.

7. *Plasmolytic Studies.*—In 1884, Professor Hugo de Vries of Amsterdam published an account of a new method for determining the osmotic capacity of cells. It is well known that in dilute solutions of neutral salts the protoplasm of active healthy cells is little affected until after the lapse of considerable time, but that in stronger solutions of the same salts there is an immediate contraction of the protoplasmic contents, together with a separation of the mass from the walls at all points except where delicate threads still maintain their hold. By a long series of experiments, de Vries determined the strength of various salts by which this contractile action could be produced, and he ascertained also the effect in different cases upon the turgescence of the cell-wall itself. The same investigator has continued his observations and extended them into a contiguous field, namely, the behavior of the so-called vacuoles, or sap cavities of protoplasm, under the influence of the various contracting or plasmolytic agents. Reserving for a later issue an extended account of the whole paper, it may now be mentioned that he has discovered an interesting fact, susceptible of easy verification, that a minute trace of ammonia causes in every case a remarkable increase in the size of the vacuoles and completely changes their capacity for absorption. The bearing of this fact upon the curious observation of Darwin on the phenomena of "aggregation" appeared worthy of immediate attention. Hastily conducted observations with reference to this,

show that the light which de Vries has cast upon the phenomena of vacuolar increase may explain many of the hitherto obscure phenomena in the absorbing cells of insectivorous plants. In a future number may be given some of the results to which hints derived from de Vries's paper have led the present writer. G. L. G.

8. *Histoire des principales Variétés et Espèces de Vignes d'origine Américaine qui résistent au Phylloxera;* par A. MILLARDET.—If the wine-growers of France have been impoverished by the ravages of Phylloxera, certainly science has been enriched by the numerous important works which have appeared in France relating to the means of checking the injury done by the two pests imported from America, the Phylloxera and the Peronospora of the vine. The previous important papers by Professor Millardet of Bordeaux on this subject are well known. In extent and abundance of new facts presented, the present work, a quarto of 240 pages with 24 admirable lithographic plates, surpasses all that he has hitherto attempted. The work originated in a memoir presented to a committee of the French Academy in 1876, and its present enlarged form is due in part to liberal private and public subscription. The introduction treats of the histological and physiological conditions which favor the resisting powers of different American species of *Vitis*. Of these, *V. rotundifolia*, *rubra*, *cordifolia*, *rupestris*, *riparia*, *cinerea* and *æstivalis* are able to resist the attacks of Phylloxera to a considerable extent, and are therefore available as stocks on which to graft in France; while, on the other hand, in *V. candicans*, *Labrusca* and *Californica* the resisting power is small, although greater than in the European *V. vinifera*. The writer, following out the views expressed in a previous paper, distinguishes between the galls produced on the smaller roots, which he calls nodosities, and those on the larger roots, which he calls tuberosities, the former being more dangerous. He considers that the destruction of the vine is not due primarily to the attack of the Phylloxera but to the growth of fungi which make their way into the roots through the nodosities whose surface becomes cracked and the interior spongy.

The main body of the work is divided into two parts. The first relates to the cultivated varieties, of whose origin, morphological characters and resisting powers a very full account is given. In his views with regard to the hybrid origin of some of the varieties he not unfrequently differs from other writers. The second part gives a description of the wild species with their distribution in North America. One can only praise the public spirit of the French people, which leads them to encourage the publication of memoirs like the above, which, from their expensive character, could not be published by a writer at his own cost, and from which a publisher could expect no profit. W. G. F.

9. *Flora Brasiliensis.*—Fascicle 95, so soon following fasc. 94, gives proof that Dr. Eichler is prosecuting his great undertaking with vigor. This goes with the *Cucurbitaceæ* (issued in 1878) and some small orders to make up vol. vi, part iv. Fasc. 95 con-

tains the *Campanulaceæ*, elaborated by Kanitz, along with the *Caprifoliaceæ*, *Valerianaceæ* and *Calyceraceæ* by C. A. Mueller of Berlin, altogether of little moment, and the *Asclepiadaceæ* by the late Dr. Fournier of Paris. The latter is an important order in the Brazilian empire, and is here amply illustrated by 51 plates. Brazil would appear to be particularly rich in genera, for fifty-six are characterized in the present work. Twenty-five of them are here founded by Fournier, eighteen of them on single species, five others have only two species each. There is one of six species (*Verlotia*), and one of four, but the latter is dismembered from *Gonolobus*. Dr. Fournier died in June, 1884, just when the printing of this monograph began, as a note by the editor informs us. The work therefore appears at a certain disadvantage. Probably many of the new genera may have to be reconsidered. A. G.

10. *Sketch of the Botanical Work of the Rev. Moses A. Curtis;* by THOMAS F. WOOD. pp. 10–31, 8vo. Raleigh, N. Car., 1885. —This pamphlet is stated to be an "Extract from the Journal of the Elisha Mitchell Scientific Society," and consists of a memoir "read before that Society at the University of North Carolina, May 22, 1885." It is pleasant to know that the University of North Carolina has such a Society, which commemorates its most distinguished scientific professor of former years, Professor Mitchell, who sacrificed his life to his zeal for investigation, on the high peak of the Black Mountain which bears his name, and where his ashes repose. Dr. Wood has in this essay erected a fitting and very interesting memorial of his old friend, the accomplished botanist, Mr. Curtis. It is full time that some such tribute to his memory was paid in his adopted State; and this will be read with interest and gratification by the few botanical companions of Mr. Curtis who still survive, and we hope also by a younger generation as well. It is illustrated by an excellent engraved portrait. A. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The apparent position of the Zodiacal Light;* by ARTHUR SEARLE.—The inquiry here undertaken by Mr. Searle was entered upon with the hope of obtaining from the older observations suggestions with regard to the apparent position of the zodiacal light after correcting them roughly for the presumed effect of atmospheric absorption. Any suggestion thus attainable will lend additional interest to the work of future observers. The positive results are however of decided value. The principal conclusions are:—

1. It is probable that atmospheric absorption largely affects the apparent position of the zodiacal light.

2. After allowance for the effect of absorption, there is reason to think that the zodiacal light, as seen during the second half of the nineteenth century, has had a more northern latitude near the longitude 180° than near the longitude 0°.

3. Upon the meteoric theory of the zodiacal light, it is to be expected that a continous zodiacal band should be present; but the question of its actual visibility is complicated by the slight maxima of stellar density which are situated along those parts of the ecliptic most readily accessible to observation from stations in the northern hemisphere.

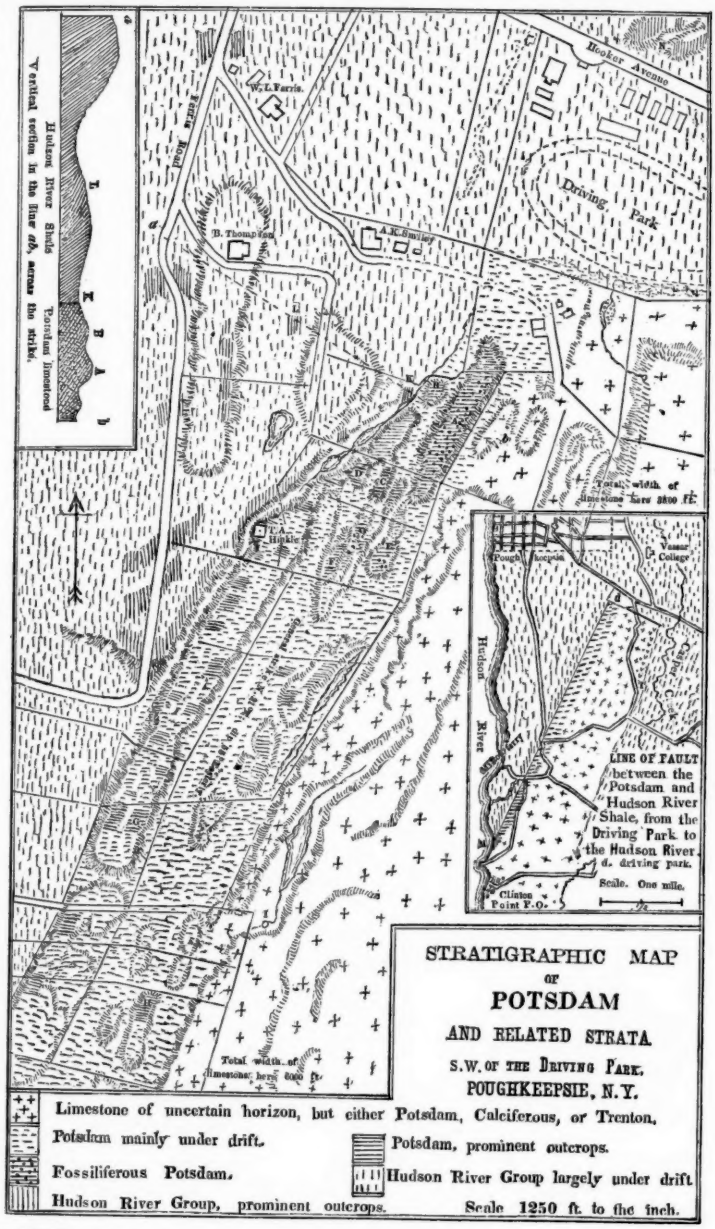
4. The belt of sky occupied by the projections of the orbits of the first 237 asteroids presents certain peculiarities which correspond to those of the zodiacal light, and suggest the hypothesis that the light may be partly due to minute objects circulating in orbits like those of the smaller planets.

Mr. Searle also finds incidentally that a stream of small stars is indicated by the Durchmusterung as extending along the ecliptic from ε Cancri to β Virginis. H. A. N.

2. "*International Exhibition of Implements against Cryptogams and Parasites.*"—The following circular has been issued by the Royal School of Viti-Culture and Œnology at Conegliano (near Venice). "The Minister of Agriculture, Industry and Commerce of Italy, in order to favor and facilitate the application of the methods of destroying the cryptogams and parasites of cultivated plants, and especially the use of the milk calx against the Perorospora (mildew) of the vine, has decreed (November 9th) the opening of an international Exhibition, and the offering of prizes for pumps, watering and pulverization implements. The Exhibition will take place at Conegliano at the Royal School of Viticulture and Œnology.

The following prizes will be awarded: 1 Gold Medal and 500 francs; 3 Silver Medals and, with each, 150 francs; 5 bronze Medals. The Ministry of Agriculture will also purchase rewarded implements to the value of 1000 francs for distribution to the Agrarian government stations and practical and special Agricultural schools.

Exhibitors must apply for admission to the 'Direzione della R. Scuola di Viticoltura ed Enologia in Conegliano,' not later than the 22d of February, 1886. The application must contain a short description of the instruments and the price of each object which is offered for exhibition. Italian and foreign inventors and makers, or their representatives, must present their machines at the model farm of the School at Conegliano by the 1st of March, 1886. On the 2d of March and following days will take place the trials and experiments for comparison, in which proprietors and viticulturists may assist. The jury that awards the prizes will present, within 20 days from the close of the exhibition, special reports about the exhibited instruments, which reports will be printed in the '*Bollettino di Notizie Agrarie*' of the Ministry of Agriculture."


Booker Avenue
Driving Park
Fiske Road
W. L. Ferris
B. Thompson
A. K. Smiley
Total width of limestone here 3800 ft.
Hopkins
Vassar College
Poughkeepsie
Hudson River
LINE OF FAULT between the Potsdam and Hudson River Shale, from the Driving Park to the Hudson River, s. driving park.
Scale. One mile.
Clinton Point P.O.
Total width of limestone here 4000 ft.
Hudson River Shale
Potsdam limestone
Vertical section in the line ab, across the strike.
STRATIGRAPHIC MAP
OF
POTSDAM
AND RELATED STRATA
S.W. OF THE DRIVING PARK,
POUGHKEEPSIE, N.Y.
Limestone of uncertain horizon, but either Potsdam, Calciferous, or Trenton,
Potsdam mainly under drift.
Fossiliferous Potsdam.
Hudson River Group, prominent outcrops.
Potsdam, prominent outcrops.
Hudson River Group largely under drift.
Scale 1250 ft. to the inch.